



**UNIVERSITY OF DELAWARE**  
**CENTER FOR COMPOSITE MATERIALS**  
INTERNATIONALLY RECOGNIZED EXCELLENCE



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# MANUFACTURING OF COMPOSITE PARTS VIA VARTM

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**UD-CCM**

**UD-CCM • 2 July 2003**

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# Examples Of Current Composite Structures Fabricated Via VARTM



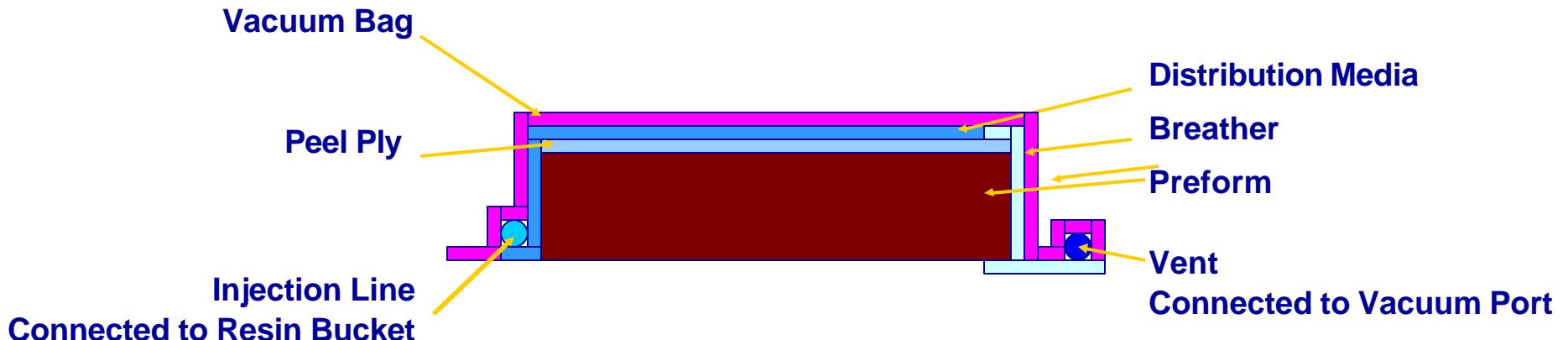
## Vacuum Assisted Resin Transfer Molding (VARTM)



# Vacuum-Assisted Resin Transfer Molding



## Schematic And Processing Sequence



### Processing Steps

PREFORM MANUFACTURING	IMPRÉGNATION STEP	CURE STEP	QA/QC
<ul style="list-style-type: none"><li>Precision Laser Cutter</li><li>Preform Binding Station</li></ul>	<ul style="list-style-type: none"><li>National VARTM Workcell</li><li>Fully Automated Injection Station</li></ul>	<ul style="list-style-type: none"><li>Induction Heating</li><li>Localized Resistive Heating</li></ul>	<ul style="list-style-type: none"><li>Fiberoptic Health Monitoring</li><li>Modal Analysis</li></ul>

# UD-CCM Intelligent VARTM Capabilities I



## ➤ Resin Characterization and New Resin Development

## ➤ Preforming

◆ Laser Cutter

◆ 3-D Preforms

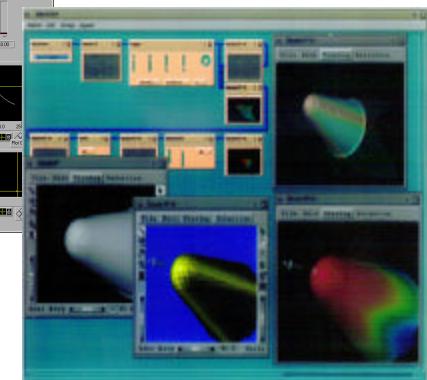
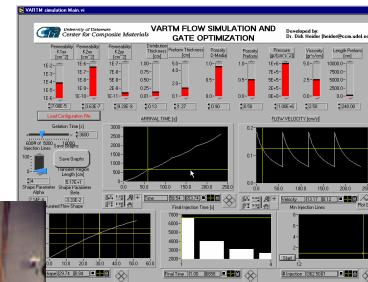
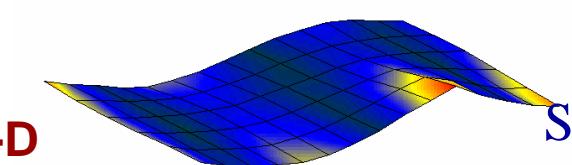
- ◆ High-Performance (3TEX)
- ◆ Binder (Solectria)
- ◆ Complex Shape (Bally Ribbon)

◆ SMART-Preforms with integrated weaved sensors

## ➤ Permeability Station

◆ 2-D

◆ Fully automated 3-D



## Simulation

3-D Liquid I  
(LIMS 5.0)

Analytical Tool for Design  
Optimization

## Sensor

Flow and Cure

Tool-Mounted  
(reusable)  
Embedded  
Tool-Mounted

2 July 2003

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# UD-CCM Intelligent VARTM Capabilities II



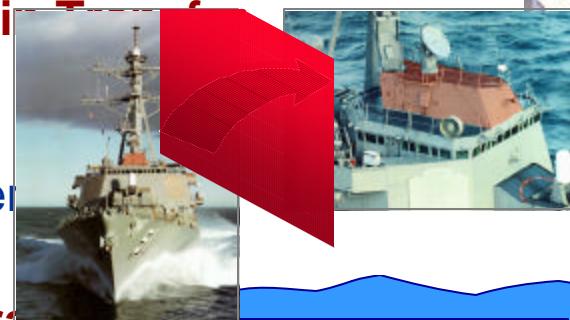
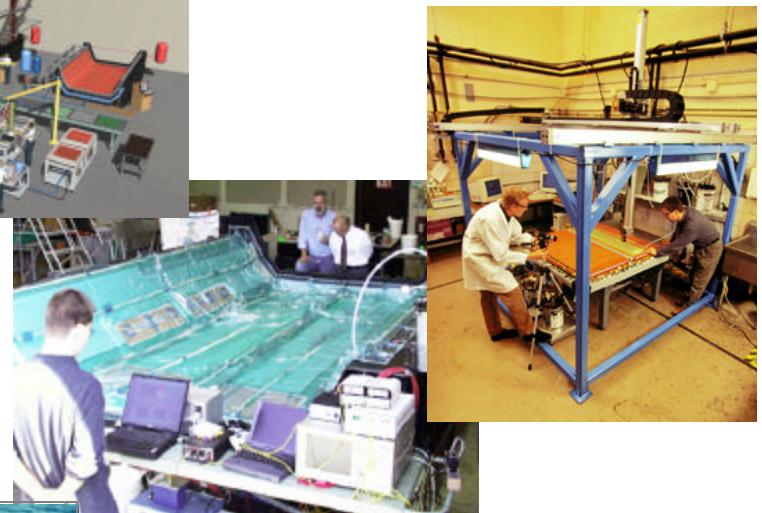
## ➤ Control and Automation

- ◆ Fully Automated Sequential Injection
- ◆ Flow Rate Control



## ➤ Advanced VARTM Processing

- ◆ RTM-like Parts
  - ◆ Surface Quality
  - ◆ Dimensional Tolerances
- ◆ Co-Injection Resin Molding
  - ◆ In-Plane
  - ◆ Layer by Layer
- ◆ FASTRAC
- ◆ Elevated Temperature



## ➤ Tooling

- ◆ Rapid Prototyping
- ◆ Rapid Water Solvable Tooling
- ◆ Reusable Bagging

## ➤ Multifunctional Materials

- ◆ Structural
- ◆ Fire
- ◆ Ballistic
- ◆ Signal

# Process Design Tool



No strong VARTM experience needed to make basic decisions on material and injection scheme

## MATERIAL DATABASE

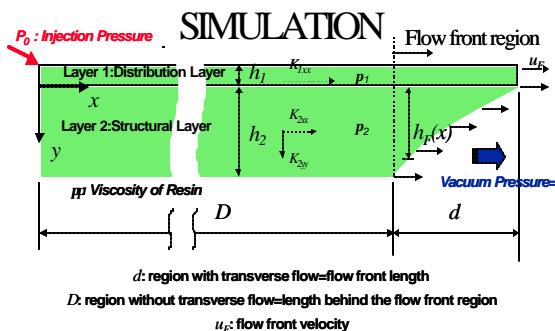
- Viscosity
- Permeability
- Infusion Temperature
- Gelation Time

Down Select

Database and Design capability can be increased over time

## PROCESS MODEL

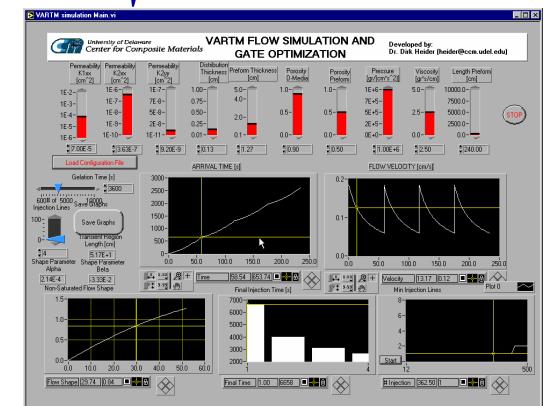
Analyze



**Flow Behavior**

- Infusion Time
- Number of Sequential Injection Lines
- Length of Non-Saturated Flow Region

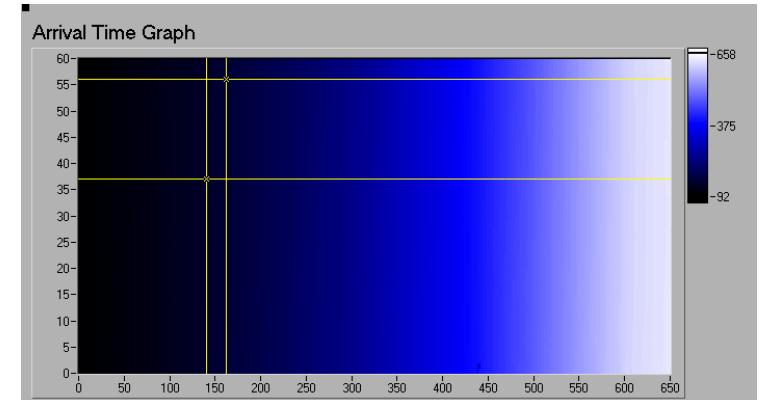
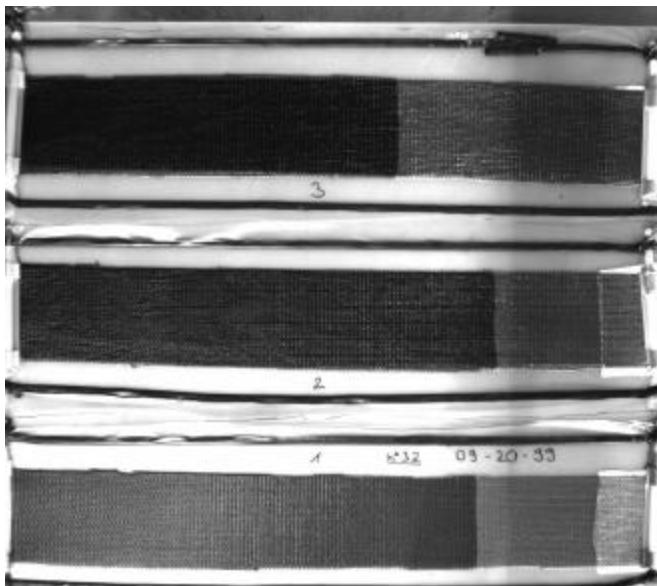
## GUI AND OPTIMIZATION



# Automated Permeability Estimation (In-Plane Only)

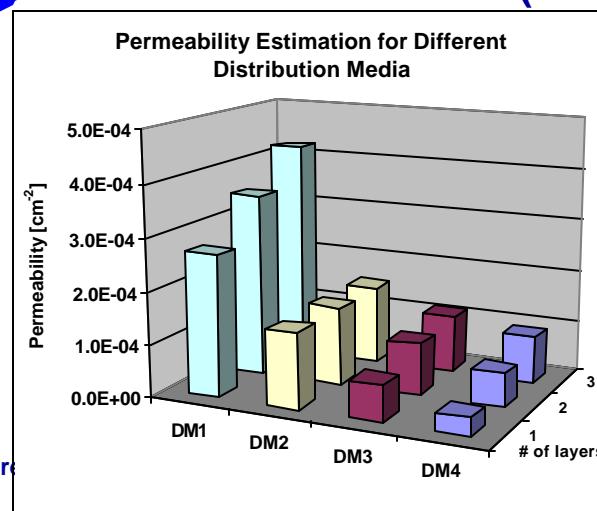


Online Capturing  
of Flow-Behavior



Post-Processing of Image Files

- Online/Offline
- Noise Reduction
- Arrival Time Calculation for all Pixels (1024x1024)



- Permeability Estimation (2D) for each preform/distribution media (Offline)
- Future work will incorporate online permeability estimation

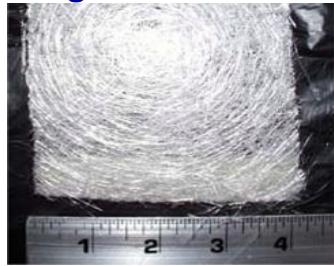


# Database: Preform Permeability

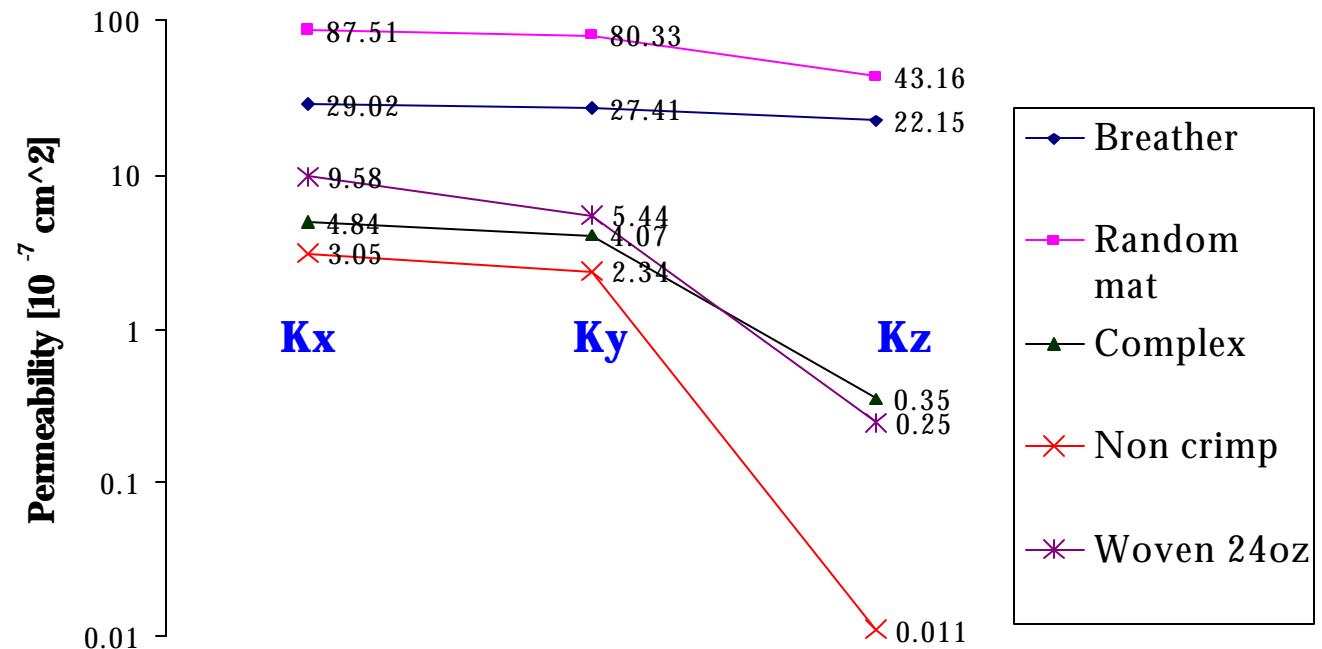
Breather:  
Airtech Airweave N10  
400g/m<sup>2</sup>



Random mat:  
Vetrotex Unifilio 816  
450g/m<sup>2</sup>



Non crimp :  
320g/m<sup>2</sup>



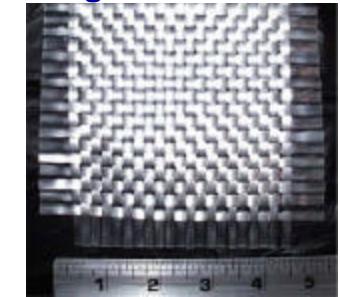
Complex:  
Vetrotex Stitchment  
2400g/m<sup>2</sup>



Woven:  
Boeing 300g/m<sup>2</sup>



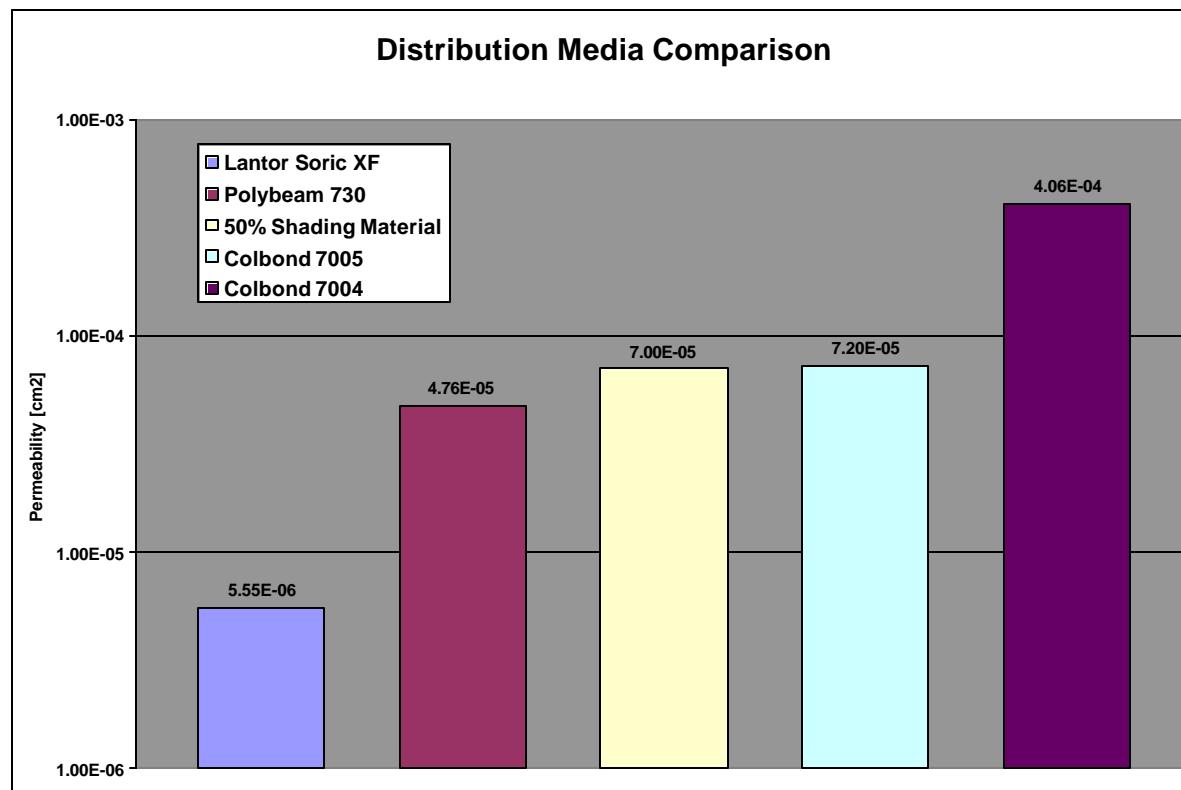
Woven:  
Vetrotex 324  
800g/m<sup>2</sup>



# Added Permeability Data to Database of Commercially Available Distribution Media

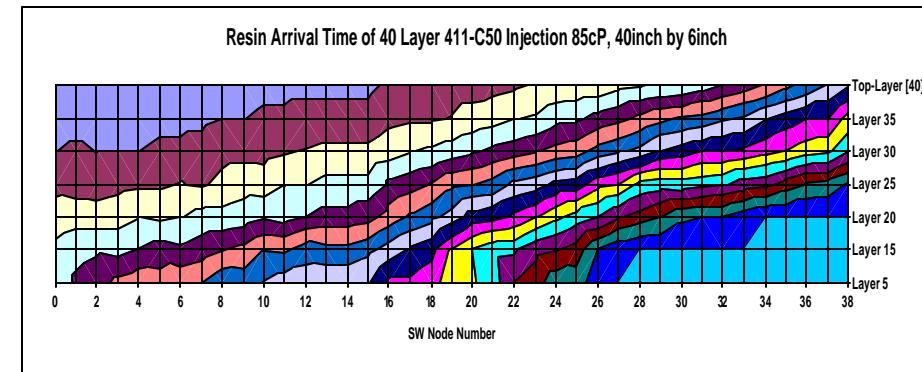
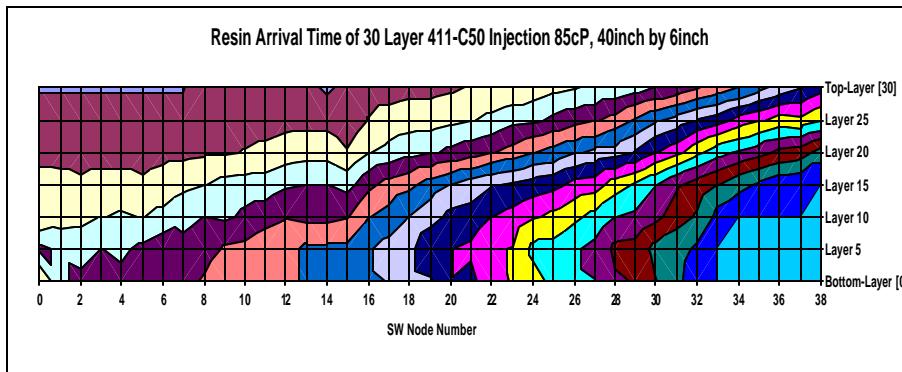
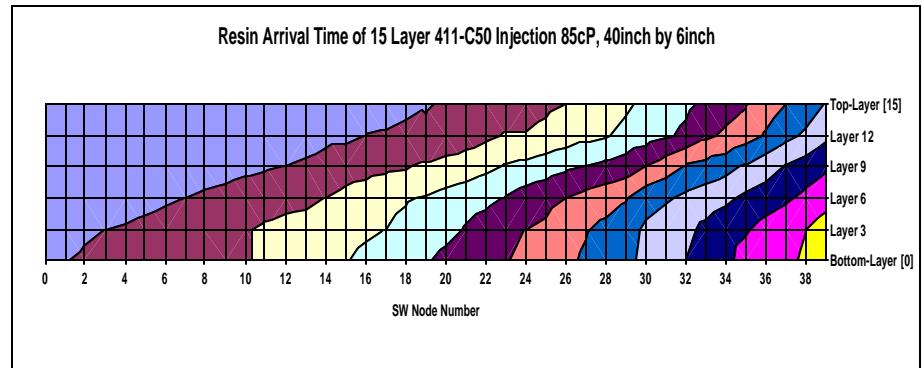
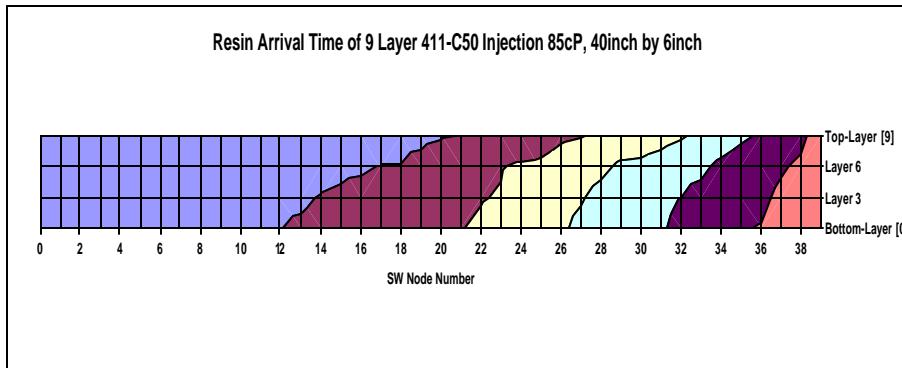


Data Courtesy  
of Gaetan  
Denis



Database includes now 5 Distribution Media (4 more in progress)  
Design tool chooses DM based on lead length and flow times

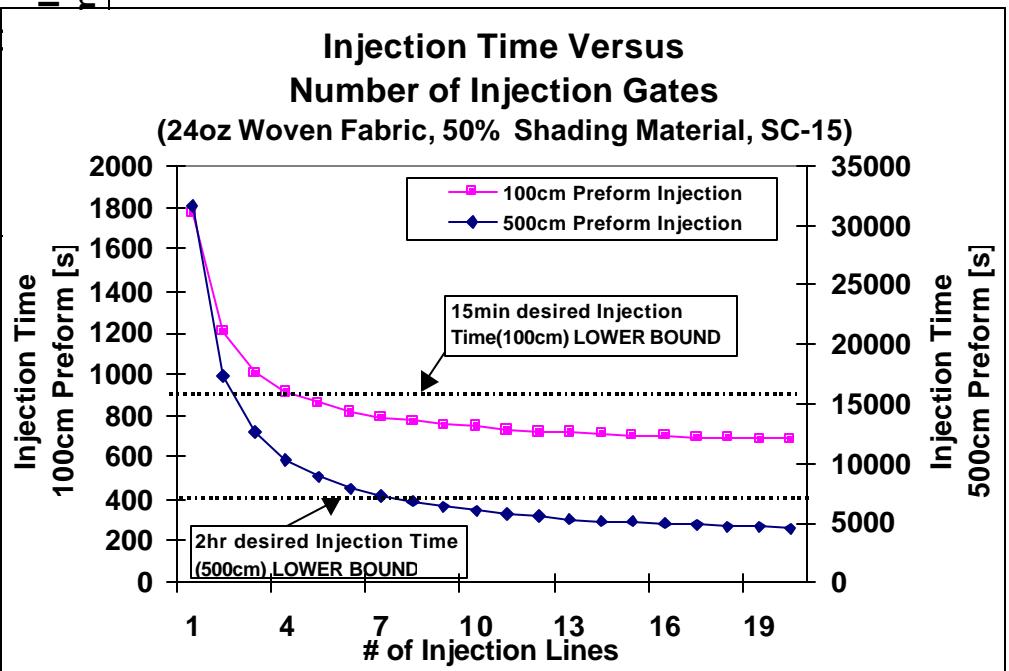
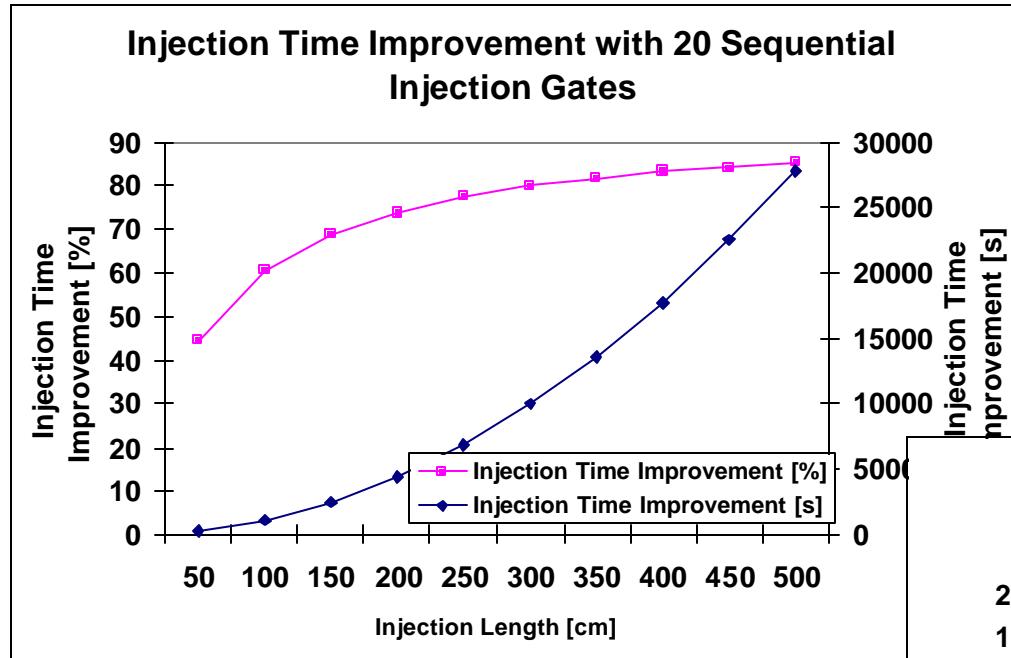
# Resin Arrival Times Measured By SMARTWeave



- Increase of non-saturated flow region with number of layers
- Resin arrival times increase linearly with number of layers
- Important VARTM feature ==> Elimination of dry spots during sequential injection with correct opening of injection ports
- Optimization of injection length (sequential injection) is important to reduce cycle times, especially for thick-section and large-scale composite parts



# Influence of Sequential Injection Lines

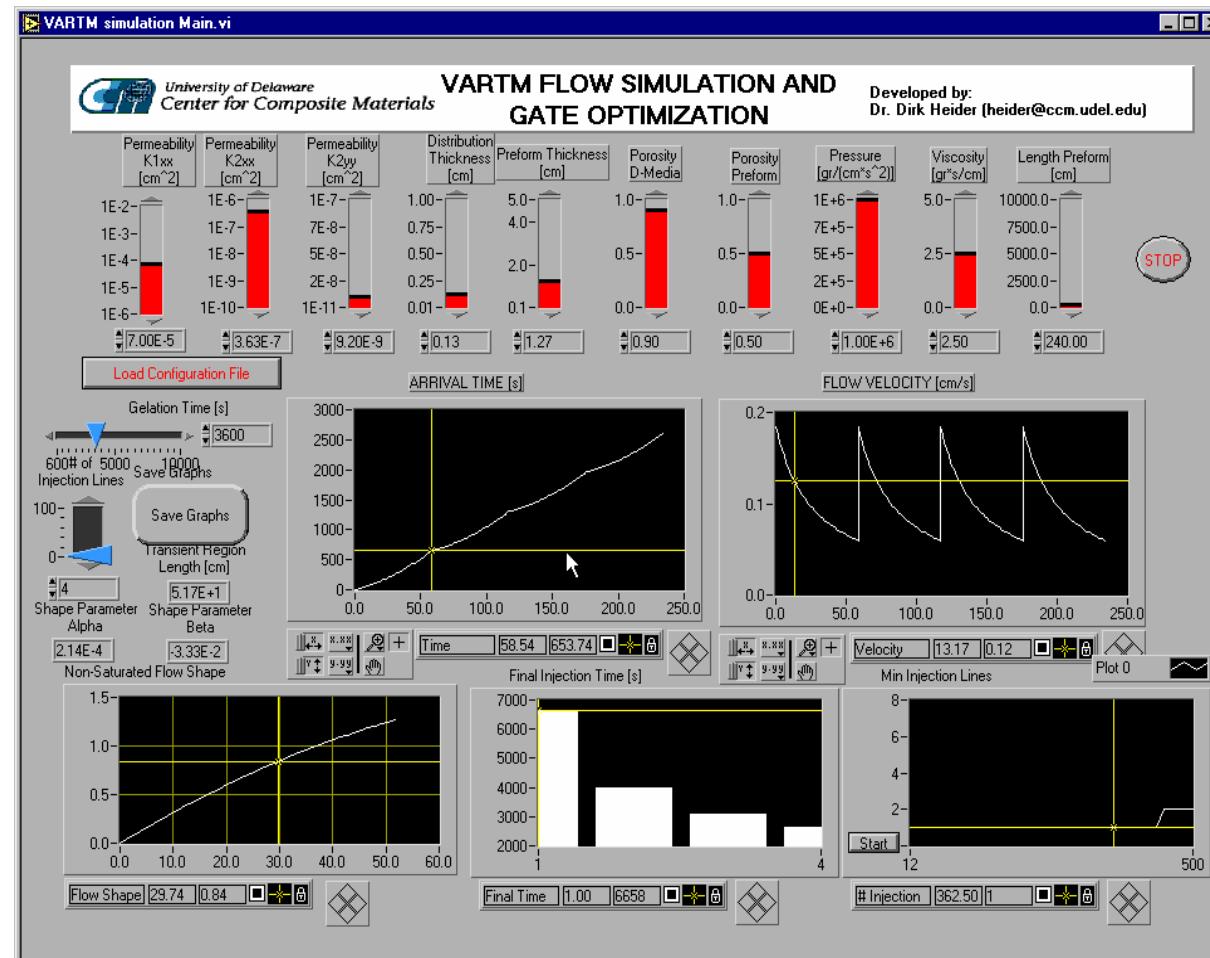


# Decisions Required for an Optimal Sequential Injection of Large Parts



1. A minimum number of inlets (lower bound for the number of inlets) are required to assure fill times are less than the gel time to ensure complete fill.
2. Increasing number of inlets will reduce cycle time but add cost (additional bagging setup (labor) and hardware requirement, resin waste, etc.). The minimum spacing and thus upper bound for the number of injection lines should be related to the flow front lead length. Analytical studies have shown that the lead length is strongly dependent on the permeability of the distribution media and the preform permeability and thickness.
3. The optimum timing for opening of the sequential injection gate is when no dry-spot can develop under the injection gate. Opening of the injection when the tool surface under the gate is wetted ensures complete wet-out and a minimum penalty on cycle time (optimum opening would be shortly before the tool surface under the gate is wetted out).

# Design Tool Demonstration



# Design Example: Hull Section



## BASELINE:

Fabric: 42 layers of 24oz. Woven Fabric

Resin: DOW Derakane Momentum

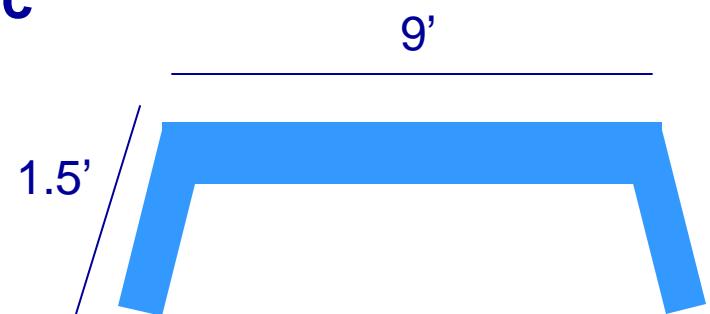
411-100 Resin

Distribution Media: 50% Shading  
Material

## Part Dimension Hull Section

- ◆ 12 feet by 8 feet by 1 inch

Infusion time approximately 30 minutes



Center injection scheme will reduce one dimension by a factor of 2

We assume injection along the width of the part

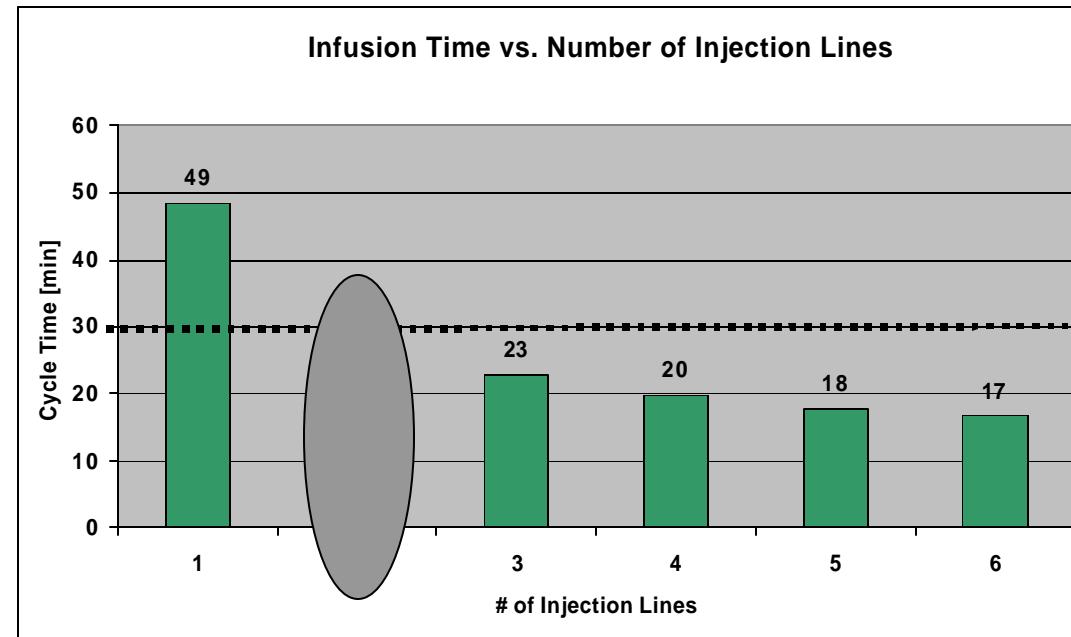
- ◆ Problem reduces to an infusion of a 6 feet part



# Design Summary

Minimum spacing given  
by non-saturated lead  
length ~50cm

→ A maximum of six  
injection should be  
used



If total infusion time should be below 30 minutes then the optimum number of inlets equals TWO (Total of three) !!!

## **Design Example II: Hull Section**

---



### **BASELINE:**

**Fabric: 40 layers of 24oz. Woven Fabric**

**Resin: Applied Poleramics SC-15 Resin**

**Distribution Media: 50% Shading Material**

### **Part Dimension Hull Section**

- ◆ **12 feet by 8 feet by 1 inch**

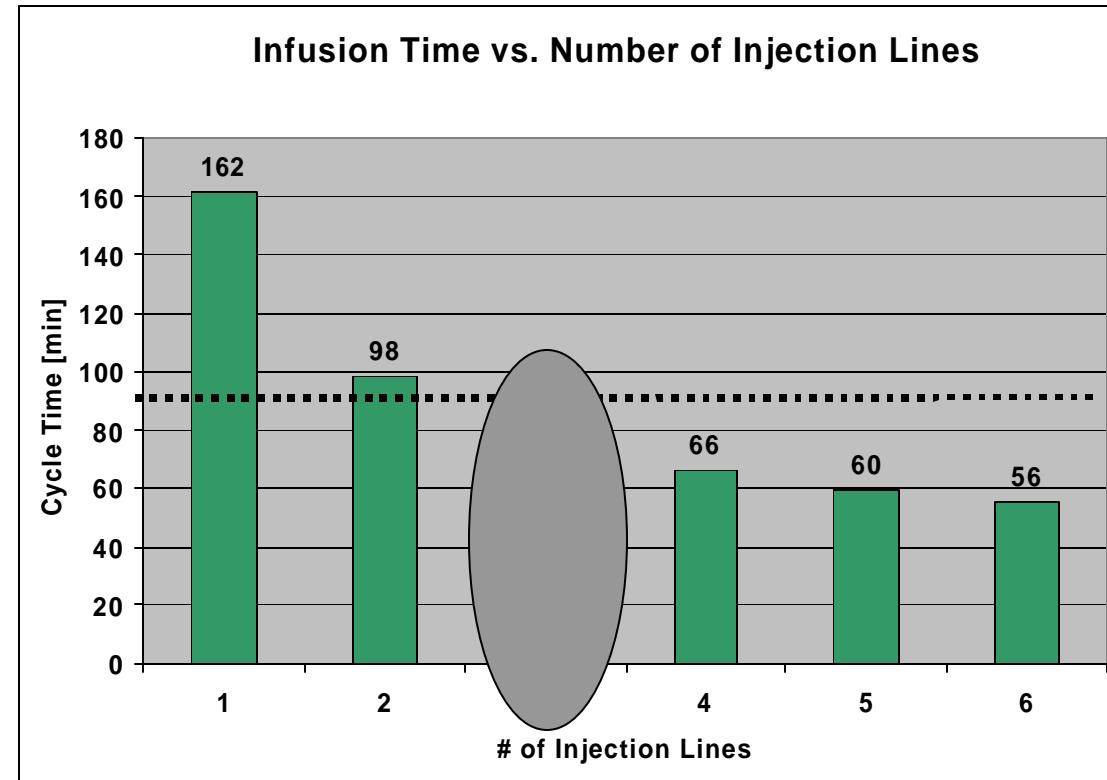
**Infusion time approximately 90 minutes (3x  
Derakane 411-100)**

**Change in resin type results in increase in viscosity  
but allows longer gelation and infusion time**



## Design II

Change in resin type results in increase in viscosity but allows longer gelation and infusion time



If total infusion time should be below 90 minutes then the optimum number of inlets equals THREE !!!

# **Design Example III**

## **Hull Section**

---



### **BASELINE:**

**Fabric: New fabric with Twice the Permeability**

**Resin: Applied Poleramics SC-15 Resin**

**Distribution Media: 50% Shading Material**

### **Part Dimension Hull Section**

◆ **21 feet by 8 feet by 1 inch**

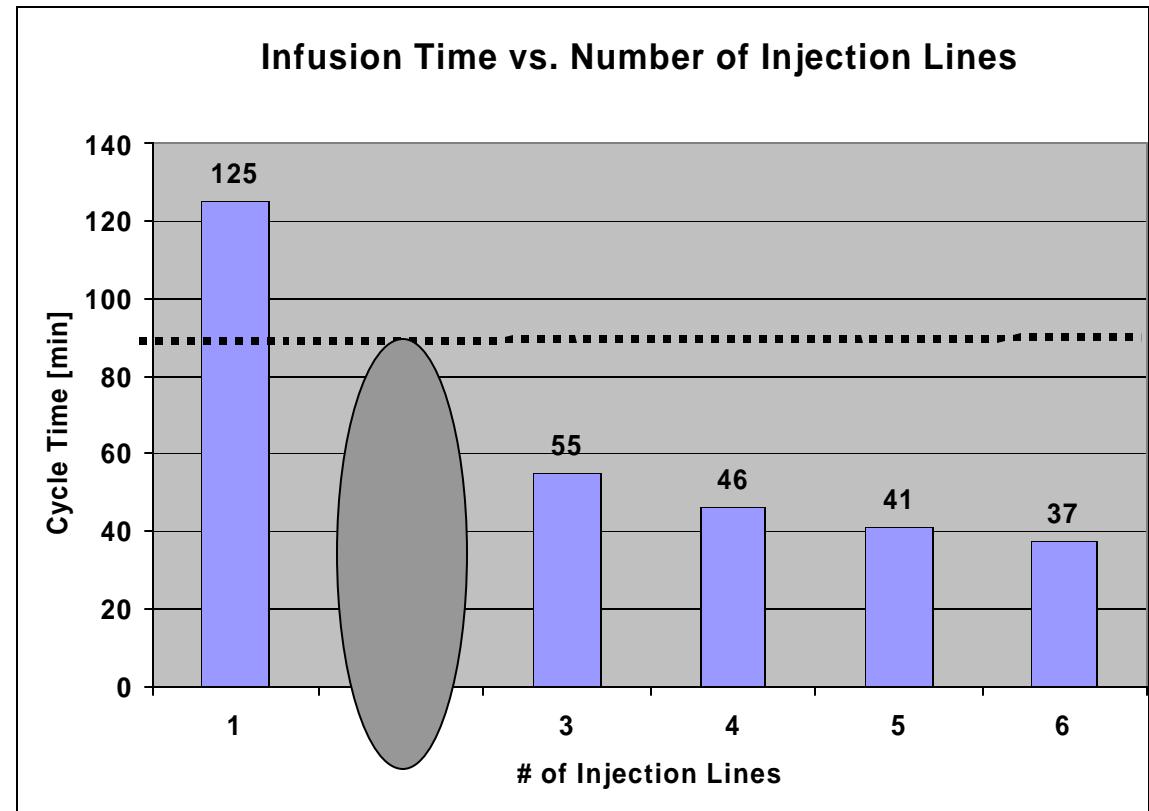
**Infusion time approximately 90 minutes**

**Change in fabric type results in increase in permeability decreasing infusion time**



## Design III

Change in fabric type results in increase in permeability allowing faster infusion

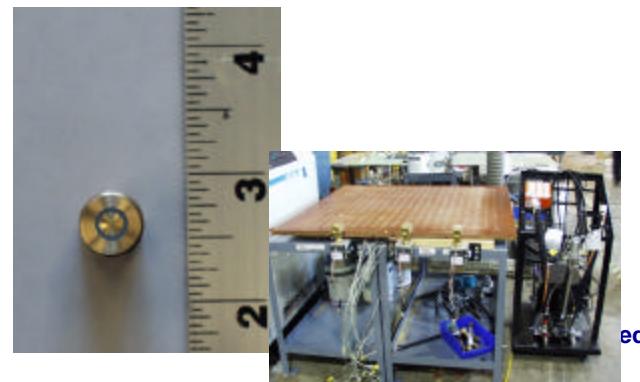


If total infusion time should be below 90 minutes then the optimum number of inlets equals TWO !!!

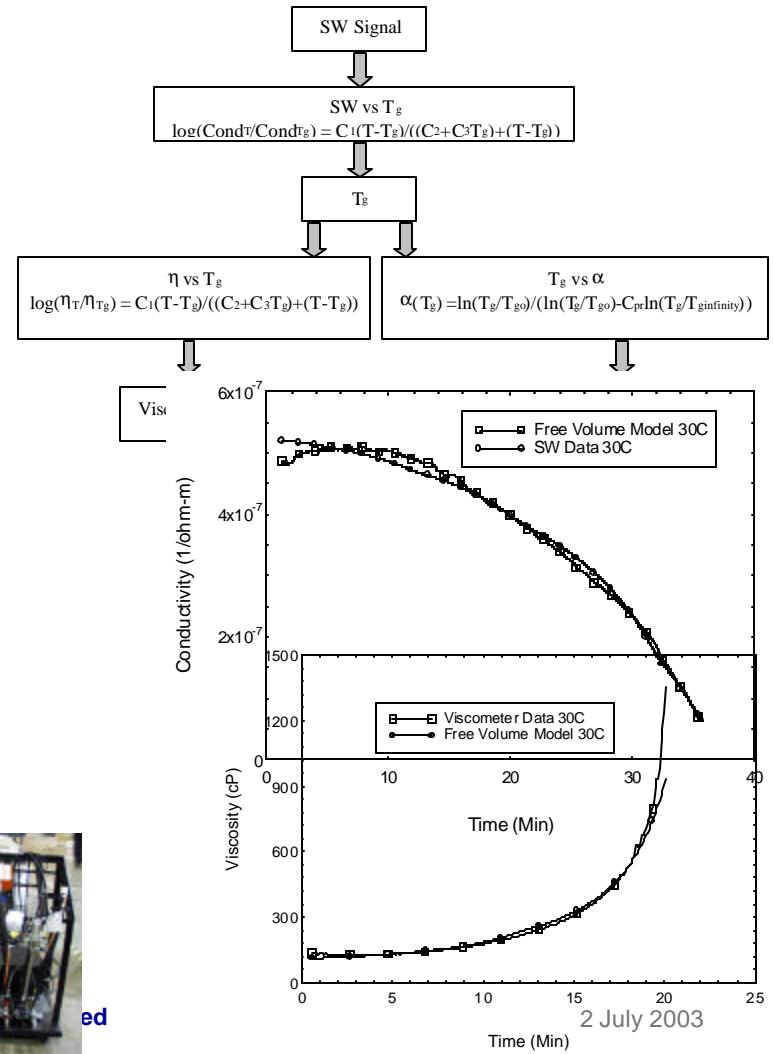
# SMARTWEAVE and SMARTMolding Sensors



- Low cost sensors measures conductivity of resin
  - ◆ SMARTweave (patented by ARL) uses embedded wires, creating nodal measurement points
  - ◆ SMARTmolding sensors are tool-mounted
- Resin arrival
- Gelation behavior



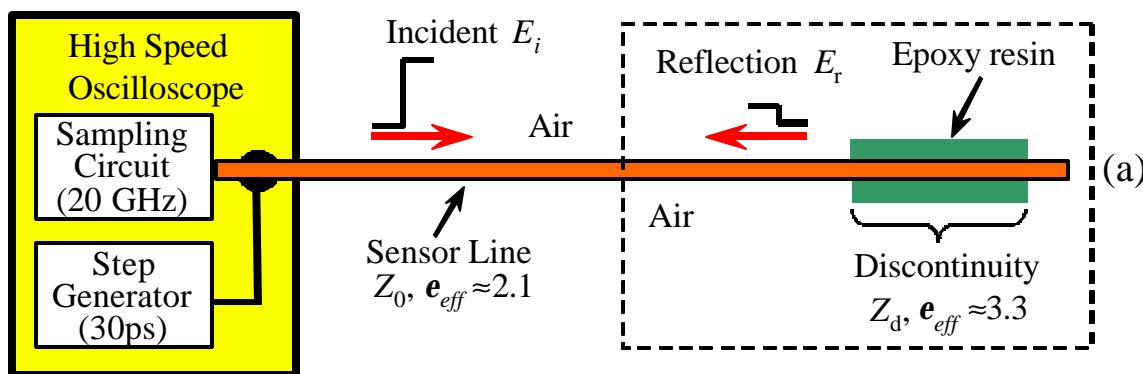
Heider ONR Workshop - 20



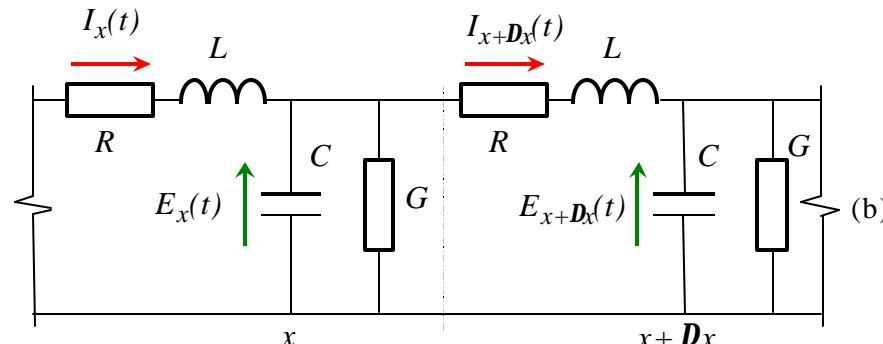
# Electric Time Domain Reflectometry (E-TDR) Approach



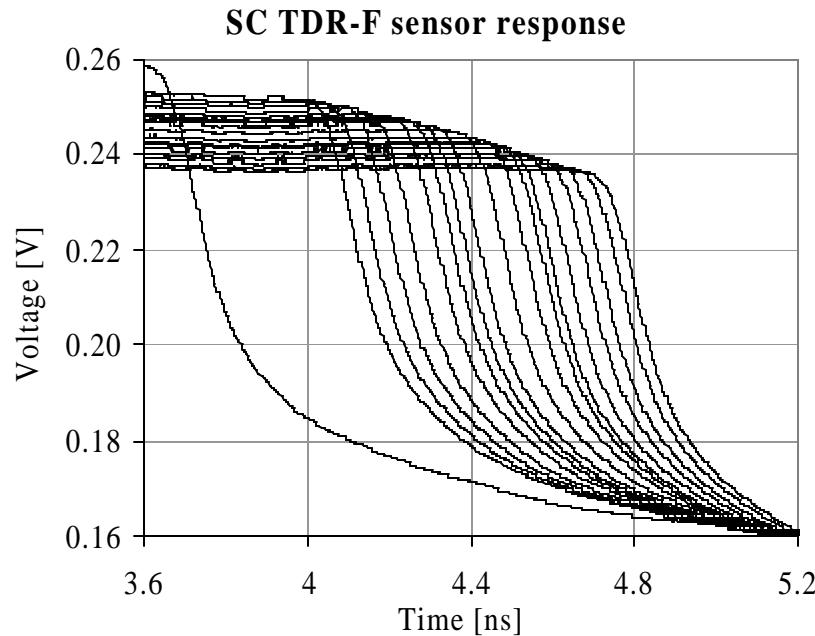
E-TDR is a method of sending a high-speed electrical pulse along a transmission line, and detecting reflections returning from impedance discontinuities within the line. In other words acquisition speed (50 GHz) is so fast that is possible to analyze transition even in short (10mm) electromagnetic circuits.



Schematic of the E-TDR technique (a) and equivalent circuit diagram of the transmission line (b).

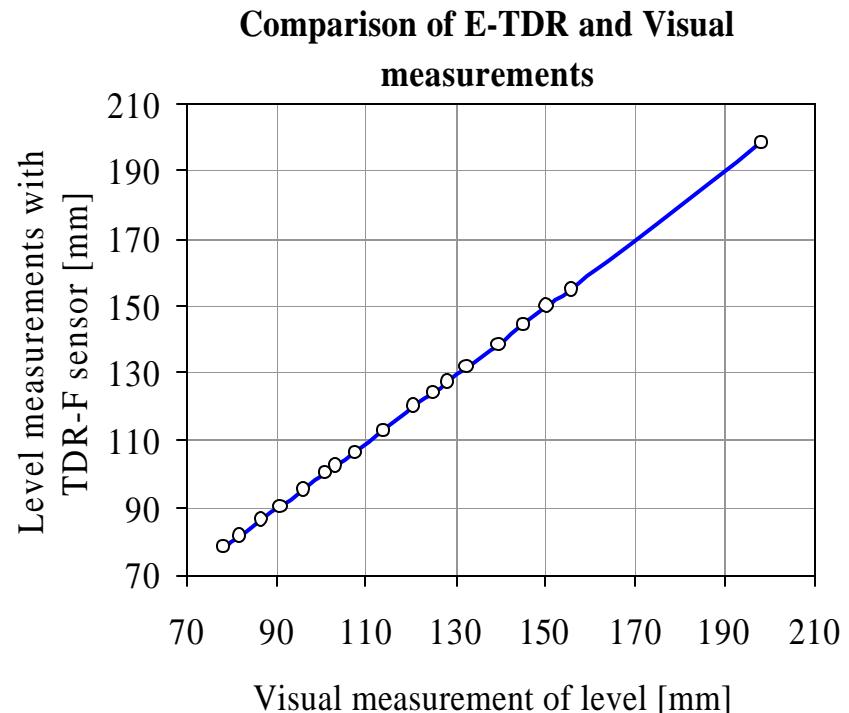


# Example: TDR Flow Measurement System Results

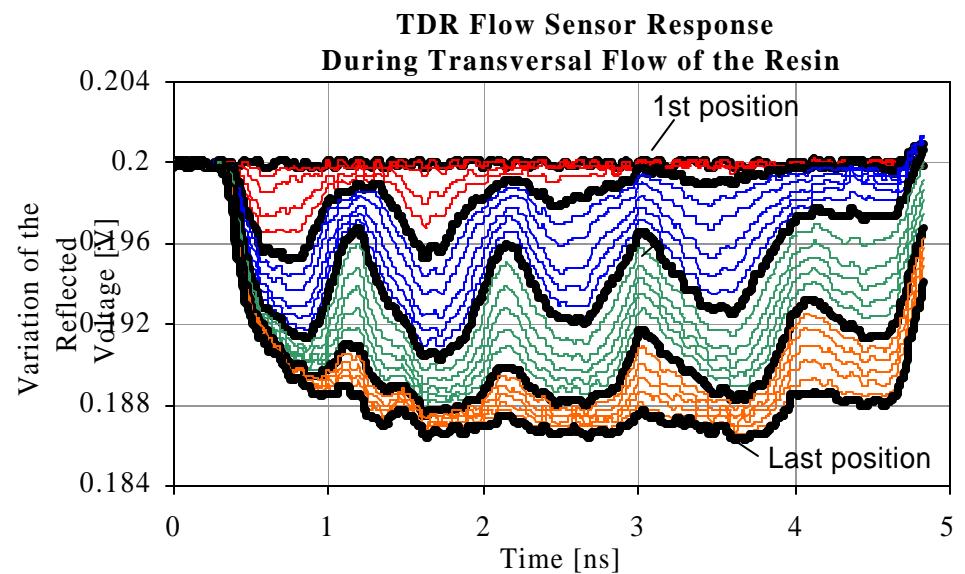
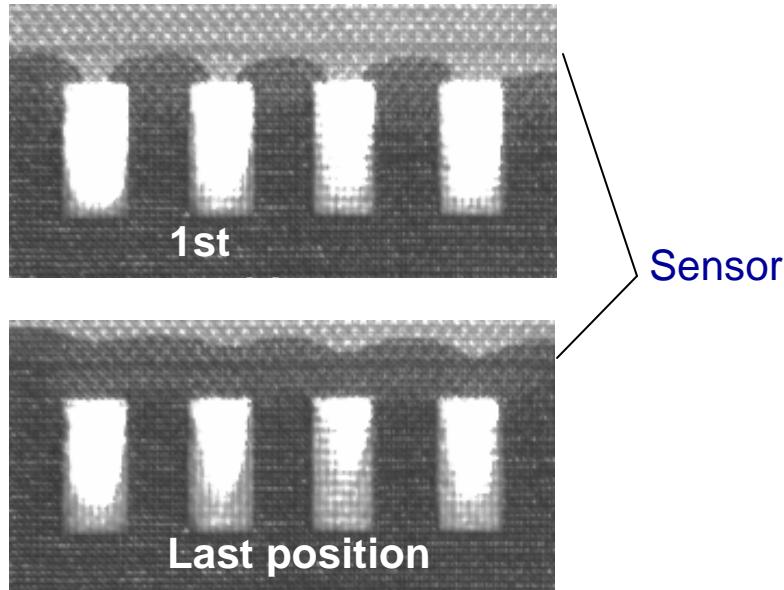


Arrival time of E-TDR sensor during level change in the U-shaped tube.

Surface coplanar transmission line gives very high sensitivity and high signal to noise ratio.



# TDR Sensor Detection of Multiple Flow Fronts

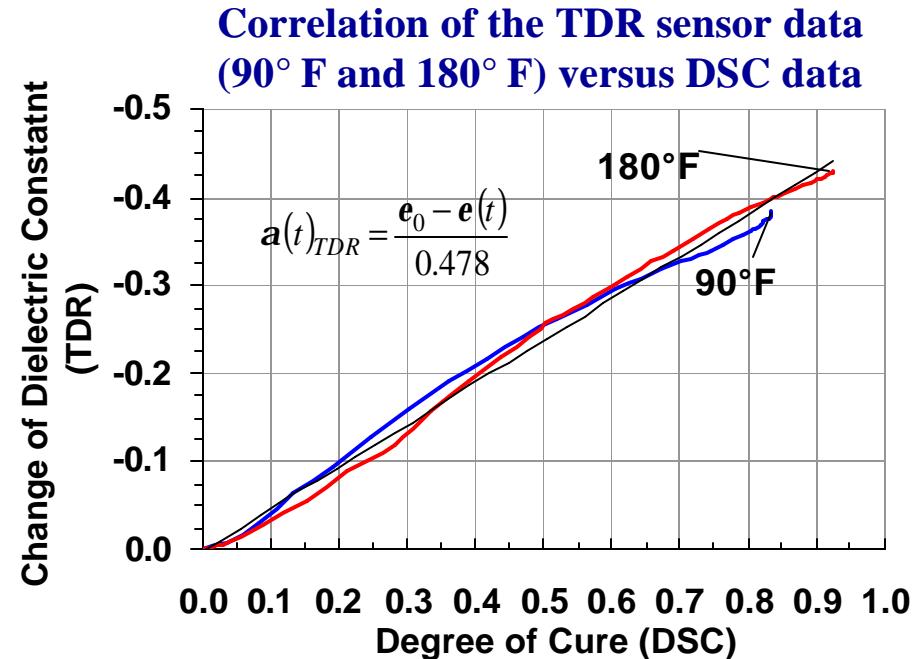
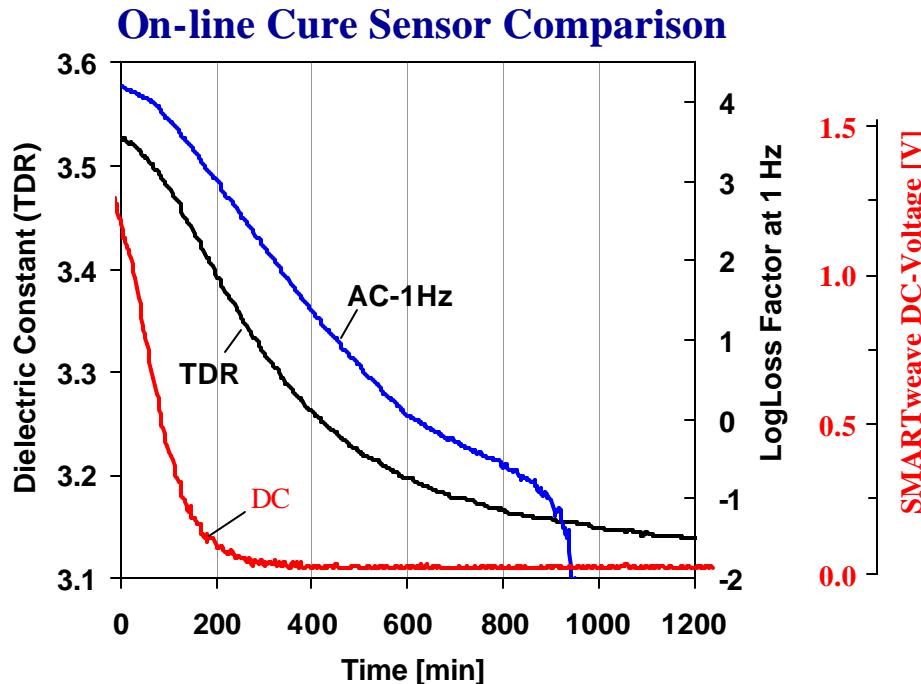


Time dependant locations of resin in the preform

Experimental data showing the movement of multiple flow fronts



# TDR Cure Monitoring



## TDR CURE MONITORING ADVANTAGES

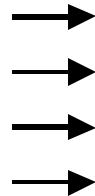
- Accurate on-line cure monitoring comparable to laboratory (FTIR and DSC) test equipment
- Low cost (flexible circuits can be mass-produced)
- Multiple sensor configurations for embedded or tool-mounted (reusable) versions are possible
- Sensing capability through intermediate layers: release agent, gel coat and others

# Motivation for an Intelligent VARTM Workcell

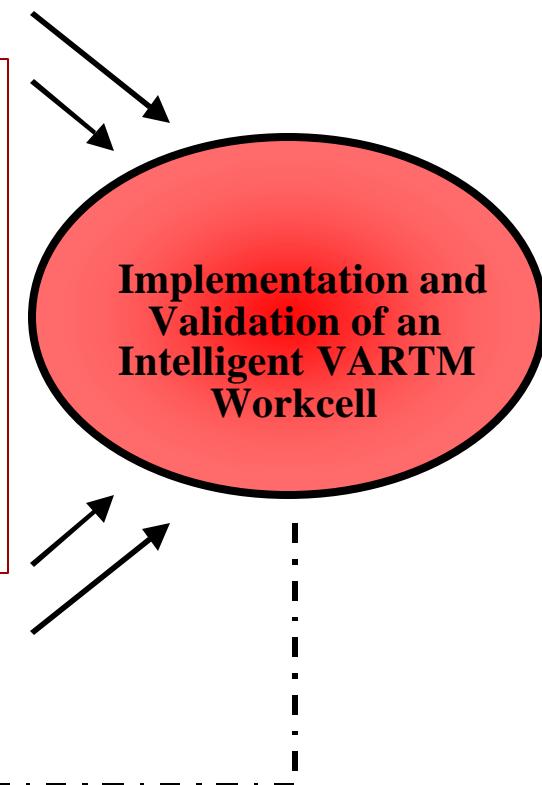


## Current Industrial Practice

- Prototypes, not production
- Trial and error
- High variability
- No automation, sensing, or control
- Manufacturing base limited to a few companies with know-how
- Costs not competitive with traditional approaches
- No two parts the same



- Design/Modeling of Infusion
- Fundamentals of mixing of reacting systems
- Controlled infusion
  - Sensors
  - Actuators
  - Software
- Preform consolidation mechanics
- QA/QC



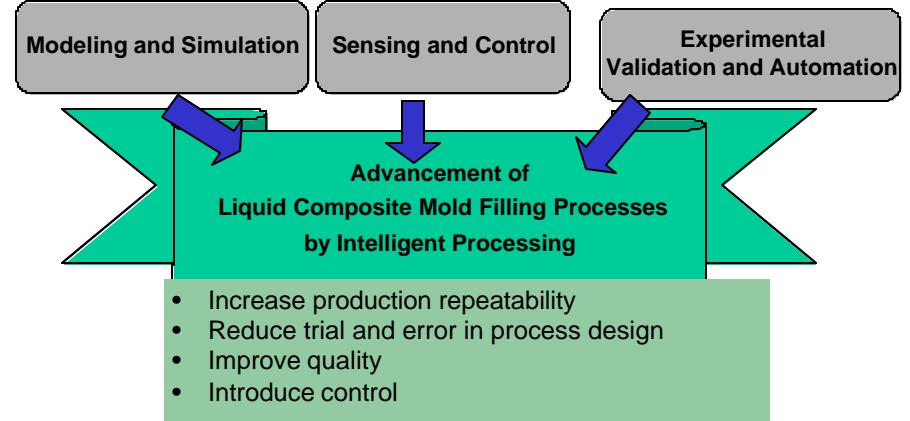
Technology Transfer



# Intelligent Process Control

**Intelligent Process Control requires**

- ◆ Real-Time Process Evaluation
  - ◆ Real-Time Process Simulation
  - ◆ Integrated Sensors
- ◆ Maximize Automation
- ◆ Learning Capability
- ◆ Network Capable



**IPC system allows**

- ◆ Repeatability
- ◆ Dimensional Control
- ◆ Scrap Reduction
- ◆ Eliminate Post-Inspection
- ◆ Increase Production Rates
- ◆ Process Traceability
  - ◆ QA/QC of Process
  - ◆ SPC
- ◆ Reduce Touch-Labor
- ◆ Reduce Cost

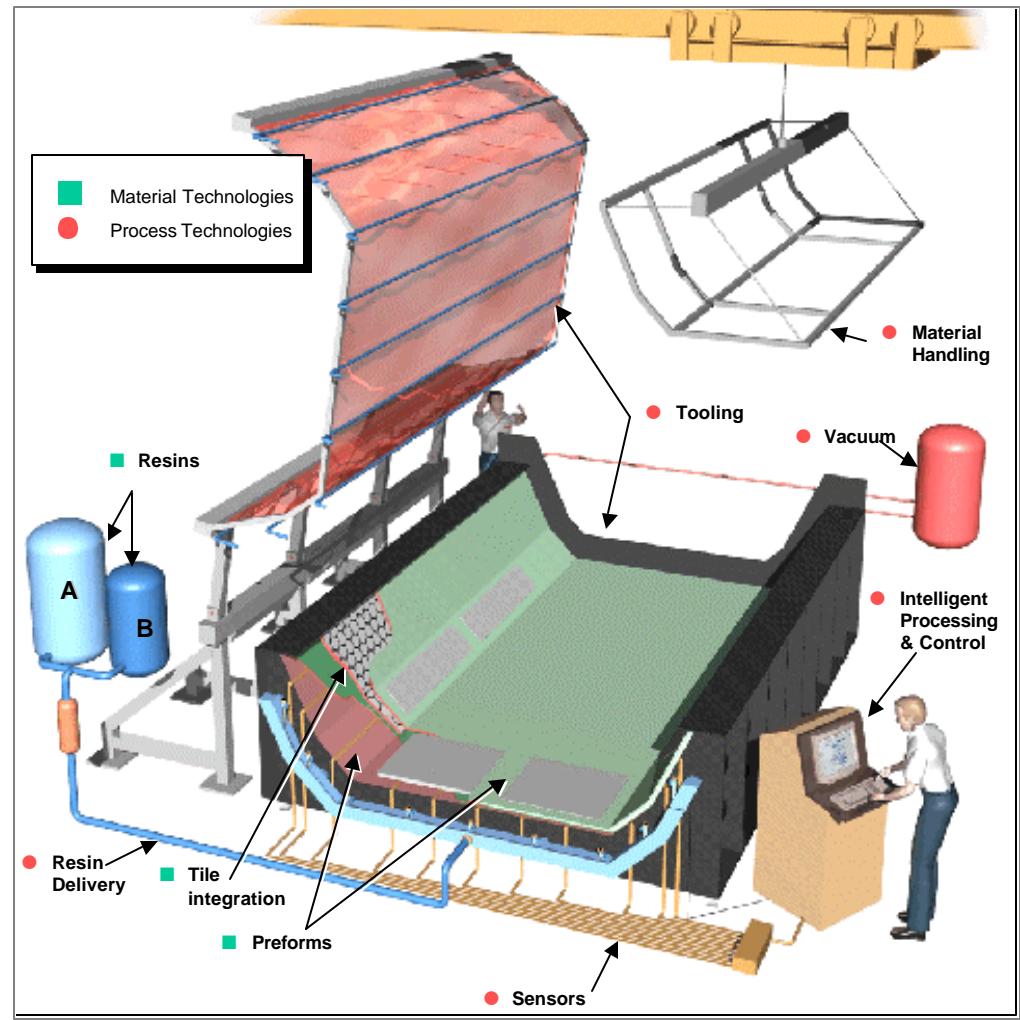


# Schematic of a Fully Automated VARTM Production Cell



## OBJECTIVES

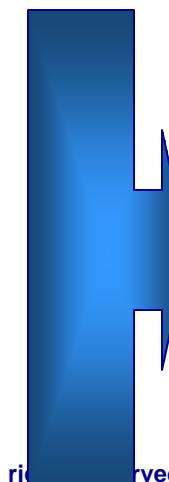
- **Automated Resin Delivery System**
  - **Smart Tooling**
    - Tool-Mounted Sensors
    - Resistive Heaters for Cure Control
  - **Automated Material Handling of Preforms**
  - **Automated Vacuum Stations**
  - **Reusable Bagging**
- **Intelligent Processing and Control**
- **Automation of all Processing Steps**



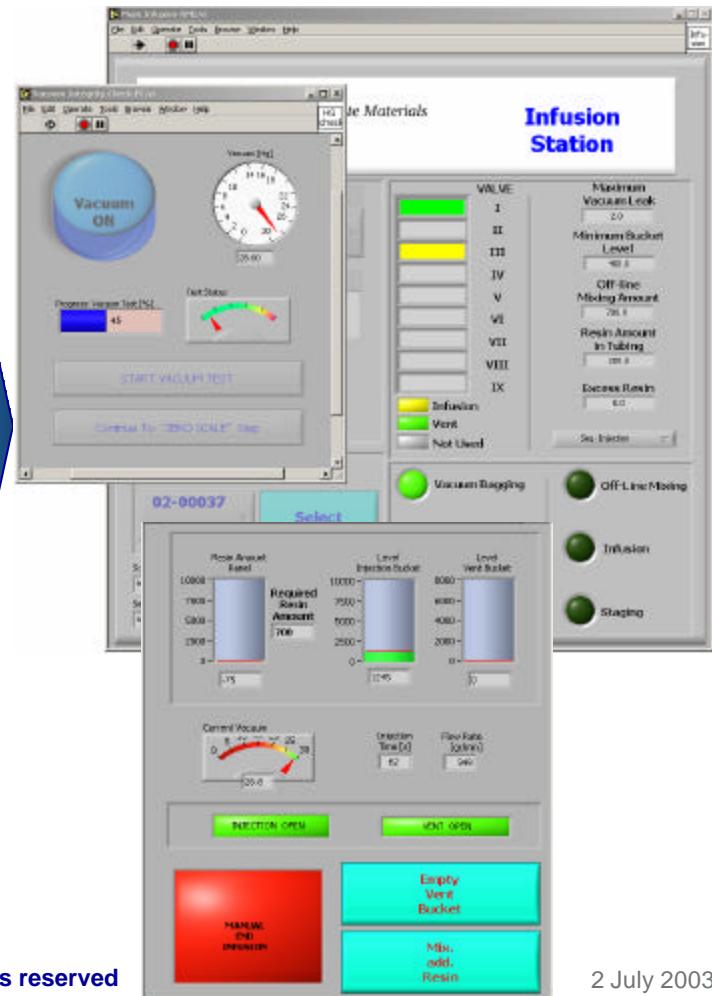
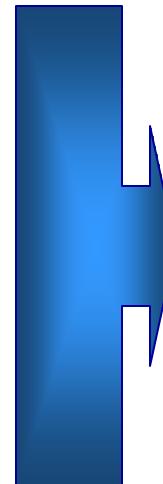
# SMARTMolding Prototype Cell



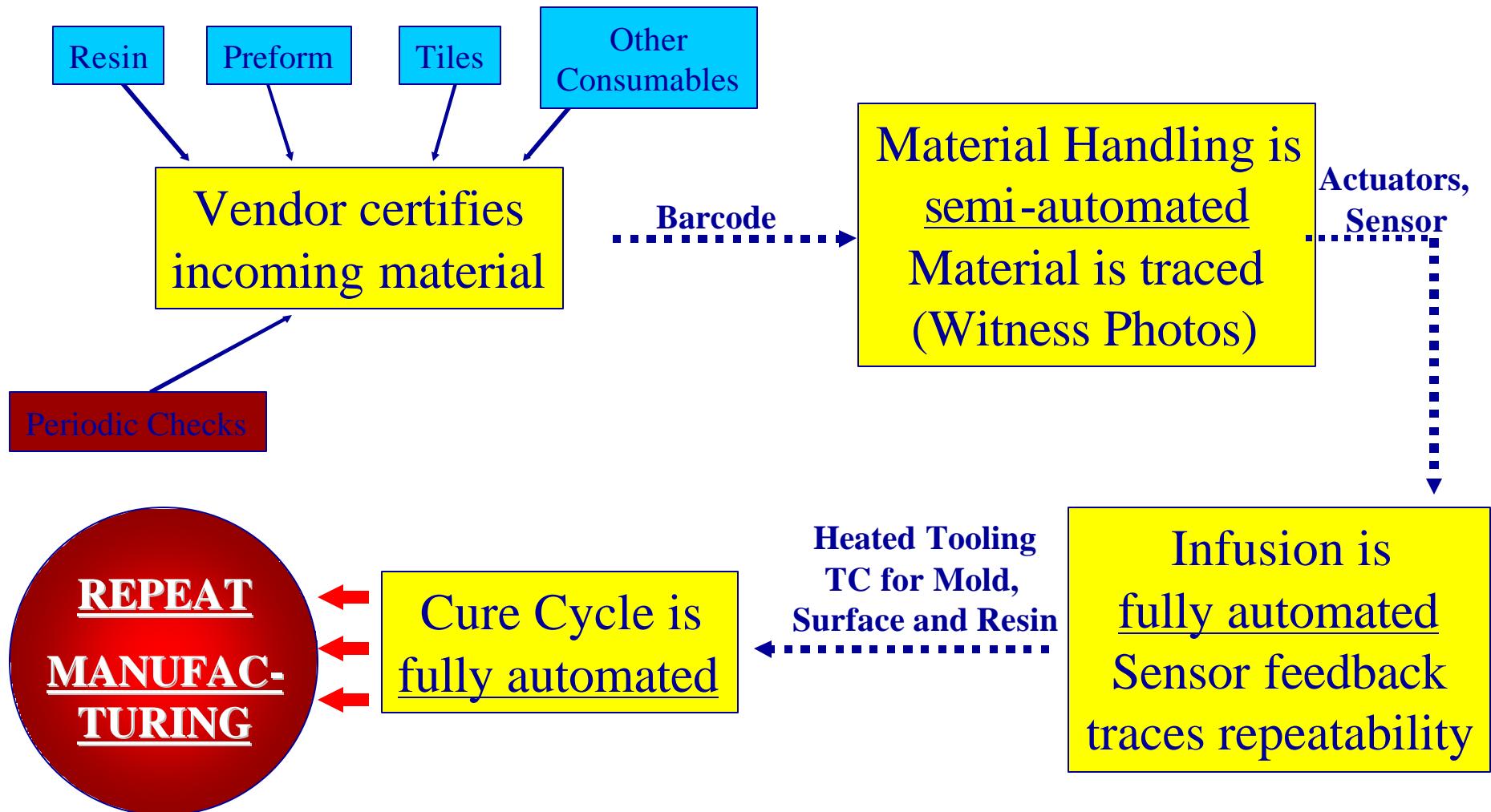
1. Manual and Automatic Control and Monitoring
  1. Pinch Valves
  2. Vacuum
  3. Precision Scales
  4. CCD-Camera
  5. Tool-Mounted SMARTMolding Sensors
2. Automation
  1. Sequential Injection Control with feedback from tool-mounted sensors



# SMARTMolding Full Production Cell



# Automation, Sensing, & Incoming Material Control Allow Repeat Manufacturing

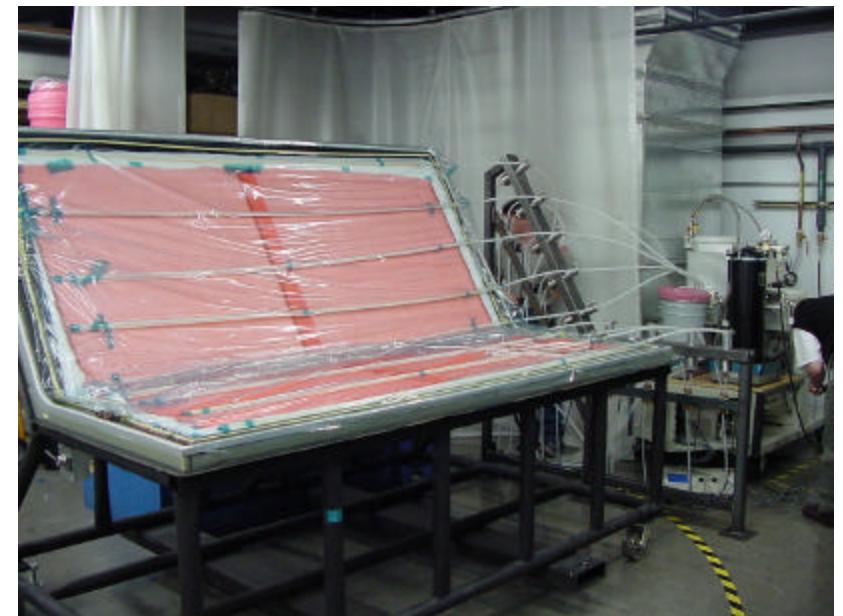




# SMARTmolding Features

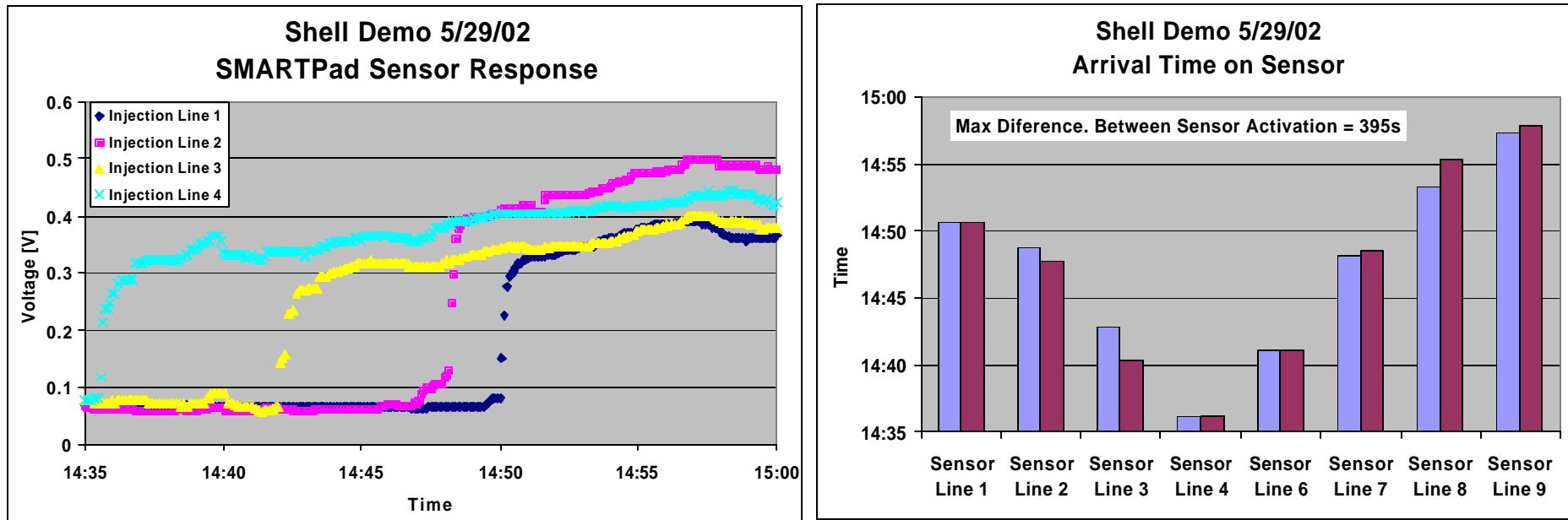
## Automation Features

- Operator Login
- Shell Selection via Barcode
- Automated Tool Selection
- Automated Vacuum Control (Infusion, Dwell) and Leak Check
- Controlled On-Line and Off-Line Mixing
- Supervised Infusion
  - Sensor Feedback from tool-mounted and/or SMARTPad sensors
  - Fully Automated opening/closing of Valves
  - Script Files for Sequential Injection
    - Process Variation Easy to Implement
    - Allows Dwell of Last Infusion Lines
- Timed Dwell (Reduction in Pressure to 7Hg) is Automated
- Process and Sensor Information are stored for QA/QC



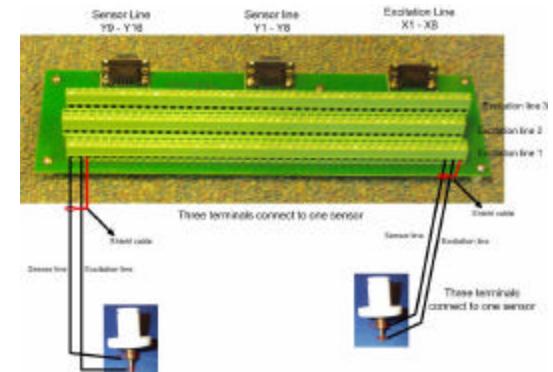


# SMARTPad Sensor Info



Two SMARTPad sensors under each injection line was attached to tool  
 New PC board was developed for simple connectorization  
 Sensor response indicates

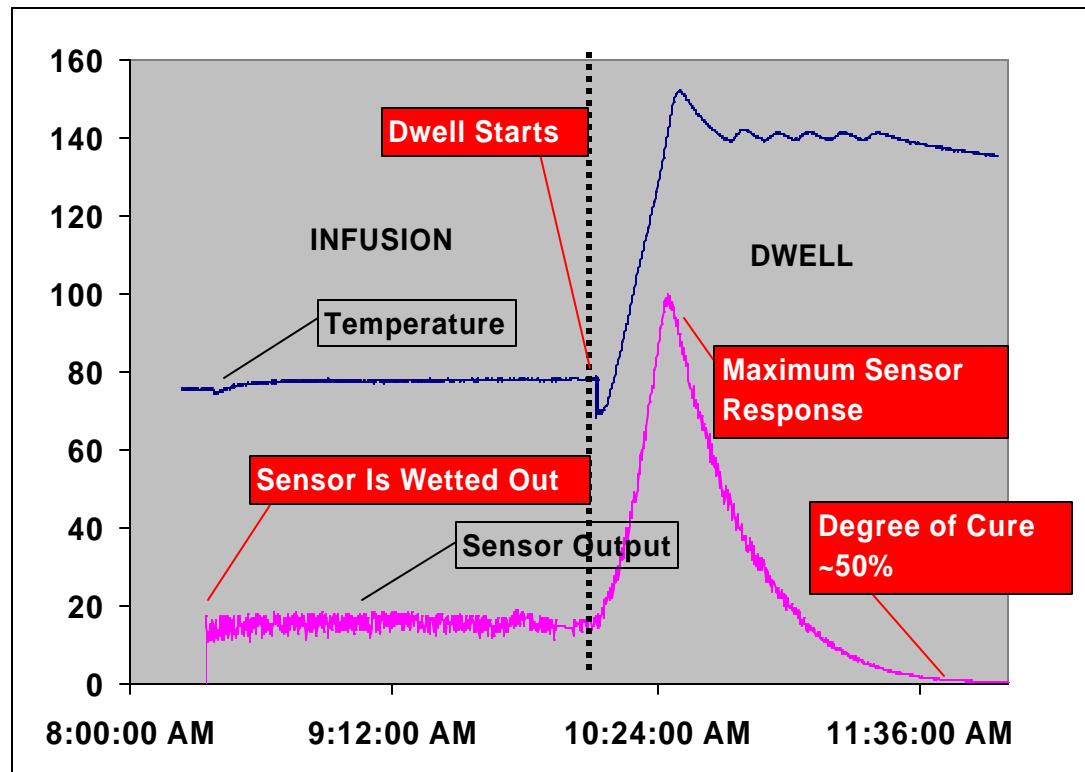
- Arrival time at each sensor
  - SPC
  - Optimization of Infusion Scheme
  - Uniformity of fabric permeability



# SMARTMolding Cure Monitoring



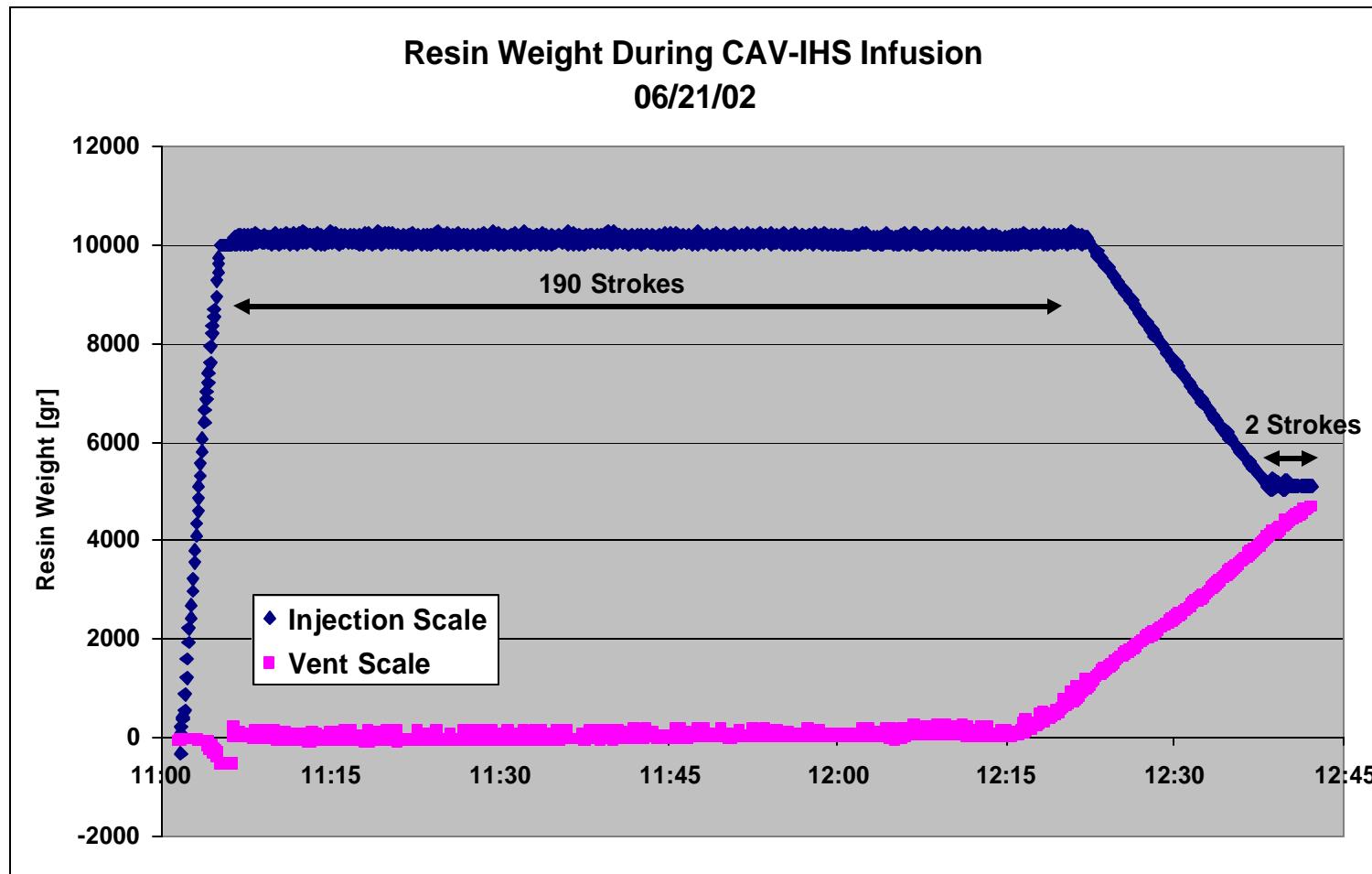
New Tool-Mounted Torlon Sensor  
New Embedded or  
Surface Mounted Flexible Circuit Sensor



Monitors resin arrival  
The degree of cure can be observed up to 50%

# Automated On-Line Mixing

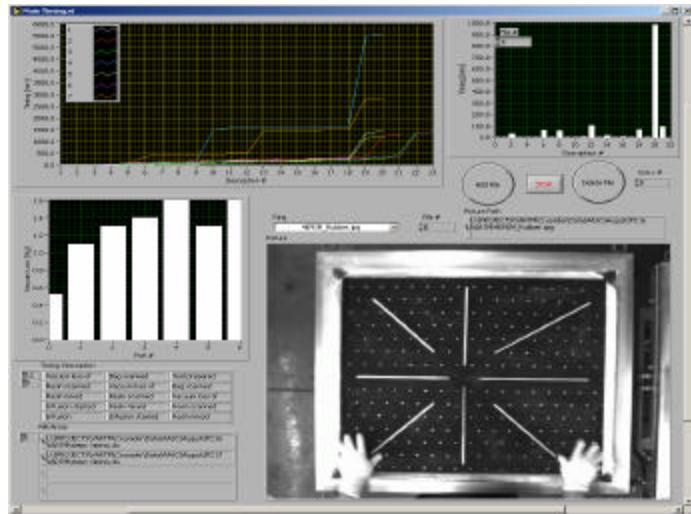
## CAV-IHS Shell Infusion



**TOTAL Automated Infused Weight: 128lb**

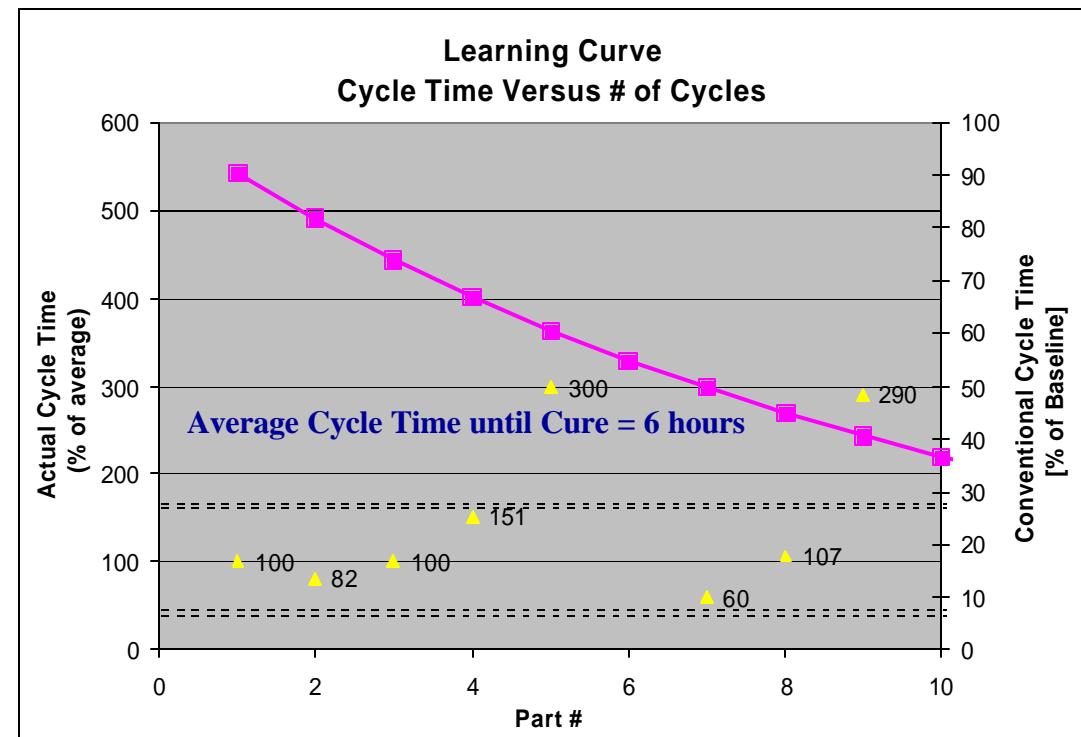
# Sensor Data Review

## Timing



Automation enables repeatable →  
processing times from cycle 1

- Individual Time For Each Processing Step Is Recorded
- Witness Photo Of Tool Fill Is Displayed
- Vacuum Loss During Vacuum Check Is Shown
- Request for Operator Comment when Actual Time Step is Larger Than Nominal





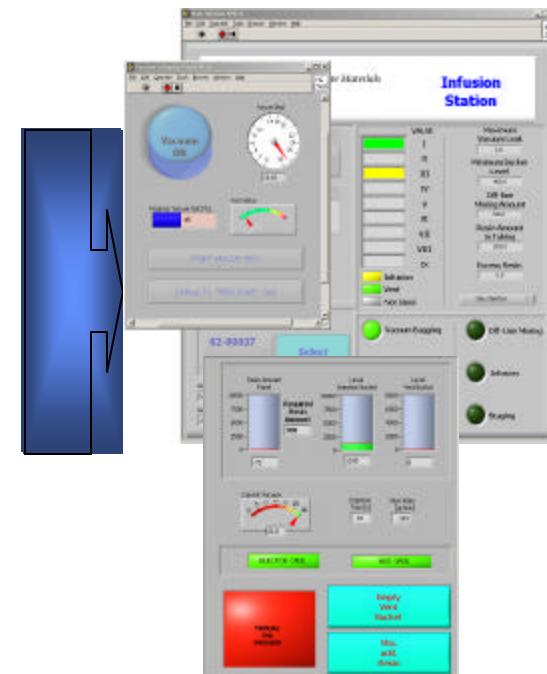
# Implementation

## Hardware

- Pinch Valves
- Vacuum Control and Sensing
  - Leak Check
- Sensors
  - Temperature
  - Flow
  - Cure
  - Scales for Flow rate



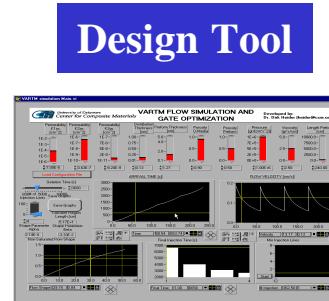
## Software



- Recipes
- QA/QC Database
- Graphical User Interfaces
  - Material Lay-up
  - Infusion
  - Cure Control



# SMARTMolding Software Suite



Simple Interface, Limited to simple geometries  
Predicts Flow Times, Lead Length  
Optimizes # of Seq. Injection Lines  
Database with Material Properties

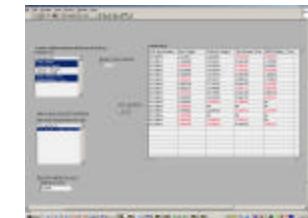


Automates the VARTM Process  
Records the processing steps  
Reporting of collected data  
Enables statistical analysis  
Guidance Software to define process recipe

## Data Review



## Statistical Package



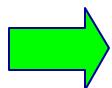
## Recipe GUI

Example	Dimensions	Material	Process	Notes
Ex1	24" by 24"	Epoxy	3C78	1
Ex2	24" by 24"	Epoxy	3C78	2
Ex3	24" by 24"	Epoxy	3C78	3
Ex4	24" by 24"	Epoxy	3C78	4
Ex5	24" by 24"	Epoxy	3C78	5
Ex6	24" by 24"	Epoxy	3C78	6
Ex7	24" by 24"	Epoxy	3C78	7
Ex8	24" by 24"	Epoxy	3C78	8
Ex9	24" by 24"	Epoxy	3C78	9
Ex10	24" by 24"	Epoxy	3C78	10
Ex11	24" by 24"	Epoxy	3C78	11
Ex12	24" by 24"	Epoxy	3C78	12
Ex13	24" by 24"	Epoxy	3C78	13
Ex14	24" by 24"	Epoxy	3C78	14
Ex15	24" by 24"	Epoxy	3C78	15
Ex16	24" by 24"	Epoxy	3C78	16
Ex17	24" by 24"	Epoxy	3C78	17
Ex18	24" by 24"	Epoxy	3C78	18
Ex19	24" by 24"	Epoxy	3C78	19
Ex20	24" by 24"	Epoxy	3C78	20
Ex21	24" by 24"	Epoxy	3C78	21
Ex22	24" by 24"	Epoxy	3C78	22
Ex23	24" by 24"	Epoxy	3C78	23
Ex24	24" by 24"	Epoxy	3C78	24
Ex25	24" by 24"	Epoxy	3C78	25
Ex26	24" by 24"	Epoxy	3C78	26
Ex27	24" by 24"	Epoxy	3C78	27
Ex28	24" by 24"	Epoxy	3C78	28
Ex29	24" by 24"	Epoxy	3C78	29
Ex30	24" by 24"	Epoxy	3C78	30
Ex31	24" by 24"	Epoxy	3C78	31
Ex32	24" by 24"	Epoxy	3C78	32
Ex33	24" by 24"	Epoxy	3C78	33
Ex34	24" by 24"	Epoxy	3C78	34
Ex35	24" by 24"	Epoxy	3C78	35
Ex36	24" by 24"	Epoxy	3C78	36
Ex37	24" by 24"	Epoxy	3C78	37
Ex38	24" by 24"	Epoxy	3C78	38
Ex39	24" by 24"	Epoxy	3C78	39
Ex40	24" by 24"	Epoxy	3C78	40
Ex41	24" by 24"	Epoxy	3C78	41
Ex42	24" by 24"	Epoxy	3C78	42
Ex43	24" by 24"	Epoxy	3C78	43
Ex44	24" by 24"	Epoxy	3C78	44
Ex45	24" by 24"	Epoxy	3C78	45
Ex46	24" by 24"	Epoxy	3C78	46
Ex47	24" by 24"	Epoxy	3C78	47
Ex48	24" by 24"	Epoxy	3C78	48
Ex49	24" by 24"	Epoxy	3C78	49
Ex50	24" by 24"	Epoxy	3C78	50
Ex51	24" by 24"	Epoxy	3C78	51
Ex52	24" by 24"	Epoxy	3C78	52
Ex53	24" by 24"	Epoxy	3C78	53
Ex54	24" by 24"	Epoxy	3C78	54
Ex55	24" by 24"	Epoxy	3C78	55
Ex56	24" by 24"	Epoxy	3C78	56
Ex57	24" by 24"	Epoxy	3C78	57
Ex58	24" by 24"	Epoxy	3C78	58
Ex59	24" by 24"	Epoxy	3C78	59
Ex60	24" by 24"	Epoxy	3C78	60
Ex61	24" by 24"	Epoxy	3C78	61
Ex62	24" by 24"	Epoxy	3C78	62
Ex63	24" by 24"	Epoxy	3C78	63
Ex64	24" by 24"	Epoxy	3C78	64
Ex65	24" by 24"	Epoxy	3C78	65
Ex66	24" by 24"	Epoxy	3C78	66
Ex67	24" by 24"	Epoxy	3C78	67
Ex68	24" by 24"	Epoxy	3C78	68
Ex69	24" by 24"	Epoxy	3C78	69
Ex70	24" by 24"	Epoxy	3C78	70
Ex71	24" by 24"	Epoxy	3C78	71
Ex72	24" by 24"	Epoxy	3C78	72
Ex73	24" by 24"	Epoxy	3C78	73
Ex74	24" by 24"	Epoxy	3C78	74
Ex75	24" by 24"	Epoxy	3C78	75
Ex76	24" by 24"	Epoxy	3C78	76
Ex77	24" by 24"	Epoxy	3C78	77
Ex78	24" by 24"	Epoxy	3C78	78
Ex79	24" by 24"	Epoxy	3C78	79
Ex80	24" by 24"	Epoxy	3C78	80
Ex81	24" by 24"	Epoxy	3C78	81
Ex82	24" by 24"	Epoxy	3C78	82
Ex83	24" by 24"	Epoxy	3C78	83
Ex84	24" by 24"	Epoxy	3C78	84
Ex85	24" by 24"	Epoxy	3C78	85
Ex86	24" by 24"	Epoxy	3C78	86
Ex87	24" by 24"	Epoxy	3C78	87
Ex88	24" by 24"	Epoxy	3C78	88
Ex89	24" by 24"	Epoxy	3C78	89
Ex90	24" by 24"	Epoxy	3C78	90
Ex91	24" by 24"	Epoxy	3C78	91
Ex92	24" by 24"	Epoxy	3C78	92
Ex93	24" by 24"	Epoxy	3C78	93
Ex94	24" by 24"	Epoxy	3C78	94
Ex95	24" by 24"	Epoxy	3C78	95
Ex96	24" by 24"	Epoxy	3C78	96
Ex97	24" by 24"	Epoxy	3C78	97
Ex98	24" by 24"	Epoxy	3C78	98
Ex99	24" by 24"	Epoxy	3C78	99
Ex100	24" by 24"	Epoxy	3C78	100



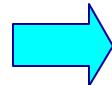
# Database Overview

## Configuration Tables



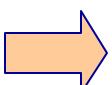
Setup (directories, DAQ settings)  
Material Info (Resin, Fabric, Core)  
Operator Info

## Recipe Tables



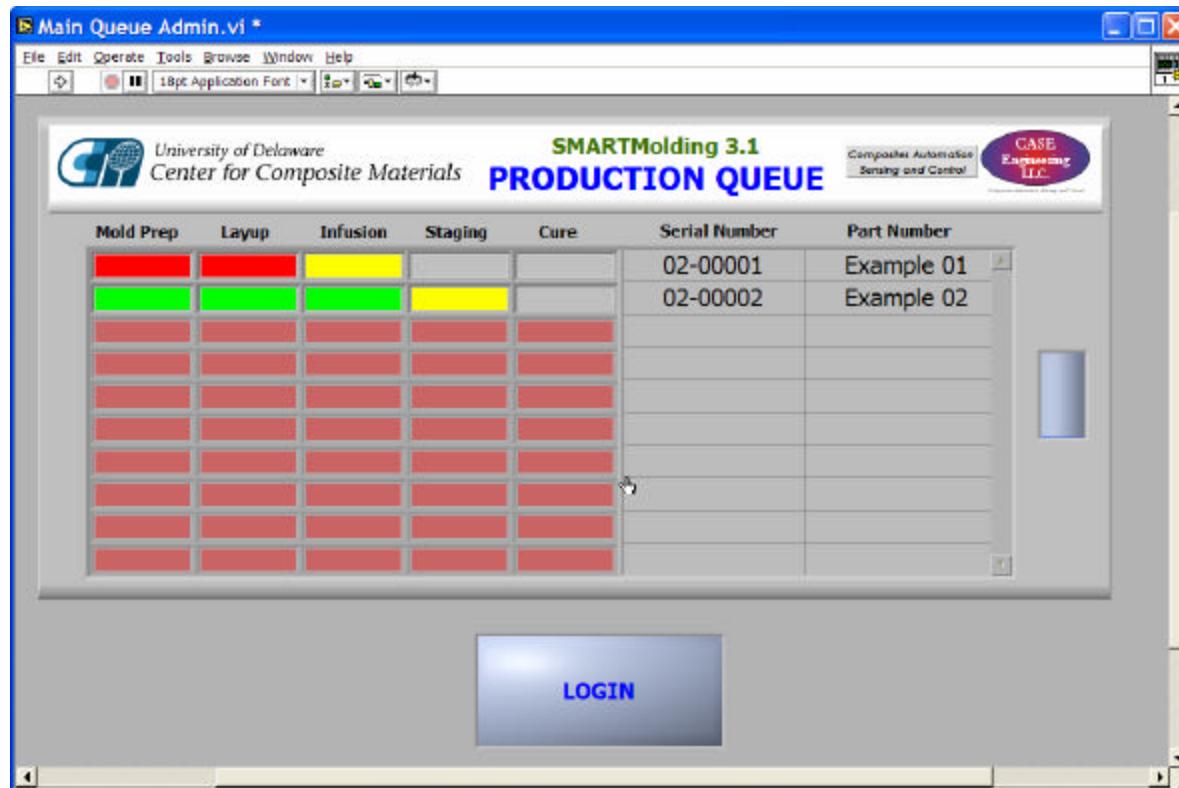
Material Sequence  
Bag and Tool Selection  
Infusion Information  
Max. Leak  
Resin Info (Amount, Type, Ratios)  
Sensor Setup  
Seq. Infusion Script (Valves ↔ Sensors)  
Dwell Info (Temperature, Time)

## QA/QC Tables



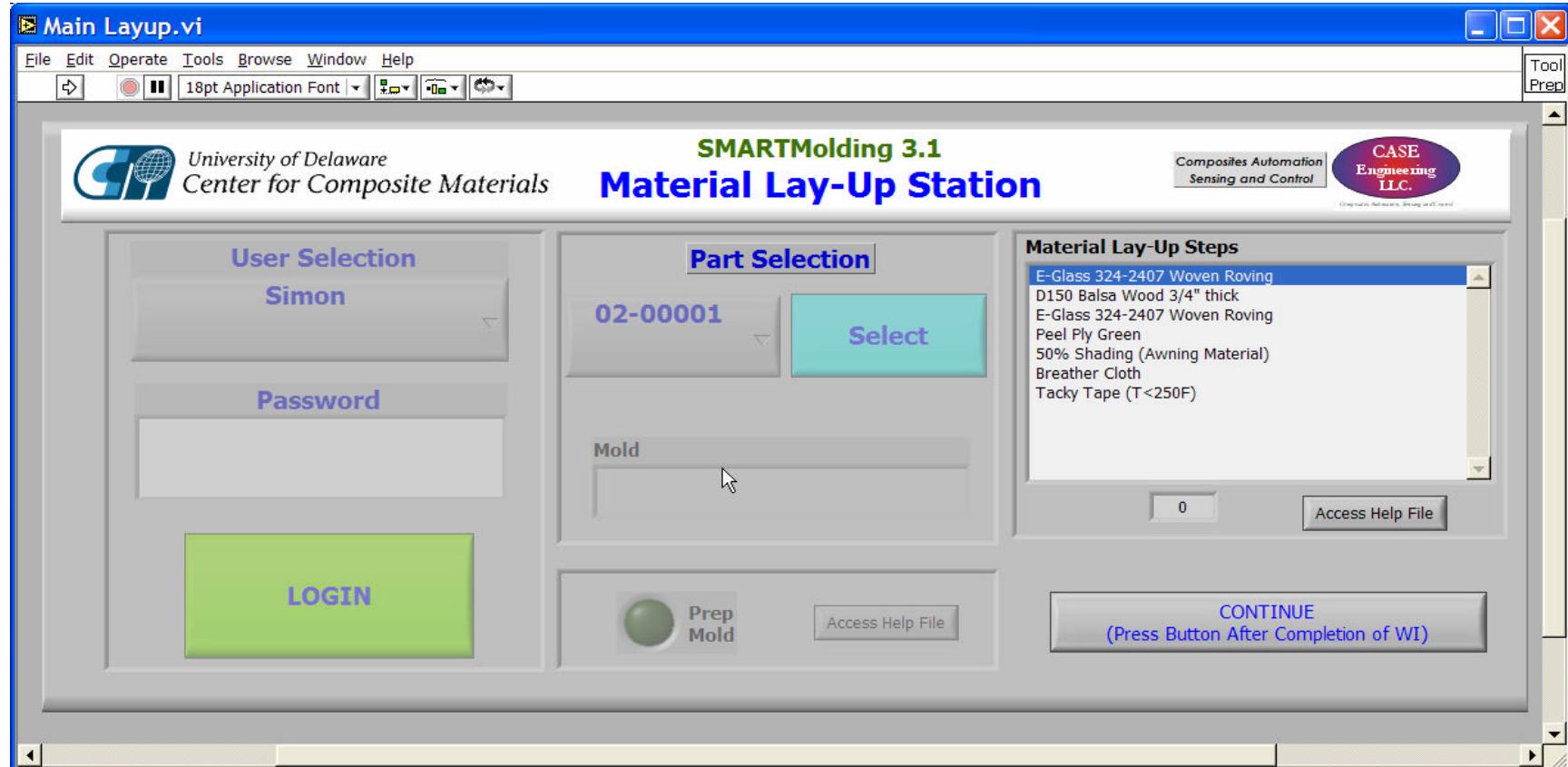
For each part  
Sensor Feedback  
Cycle Time

# Manufacturing Queue



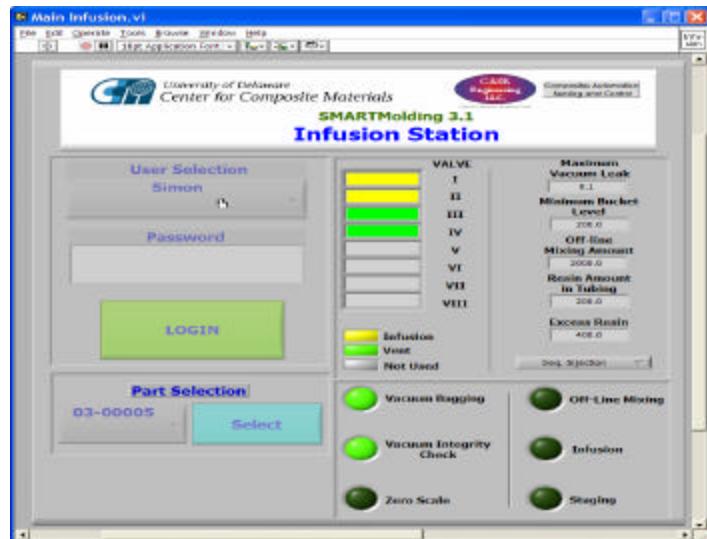
- Allows central administration of VARTM production
- Enables monitoring of production status

# Material Lay-up Station



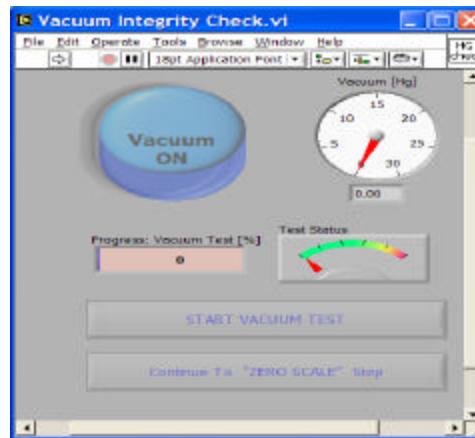
- Login feature
- Automatic part selection
- Recording of cycle time
- On-line help via work instruction

# Infusion Station

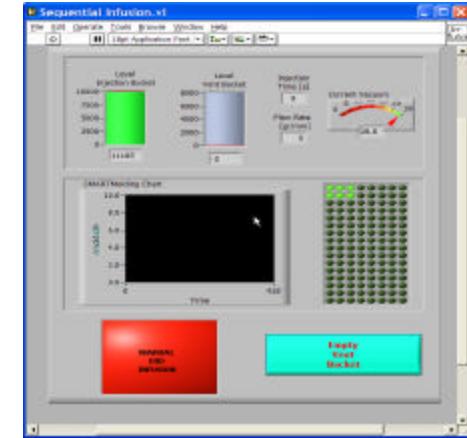


(a)

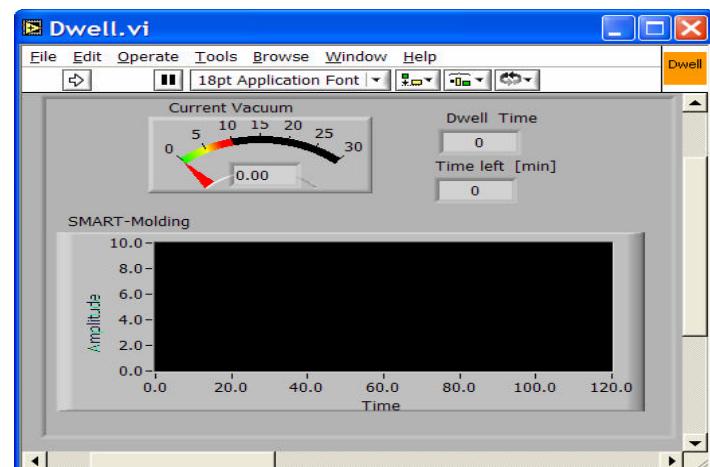
- Login feature
- Automatic part selection
- Recording of cycle time
- On-line vacuum integrity check (Figure b)
- Allows integration of industrial mixer hardware
- Sequential Injection automation (Figure c)
- Timed room-temperature dwell (Figure d)
- Records sensor feedback



(b)



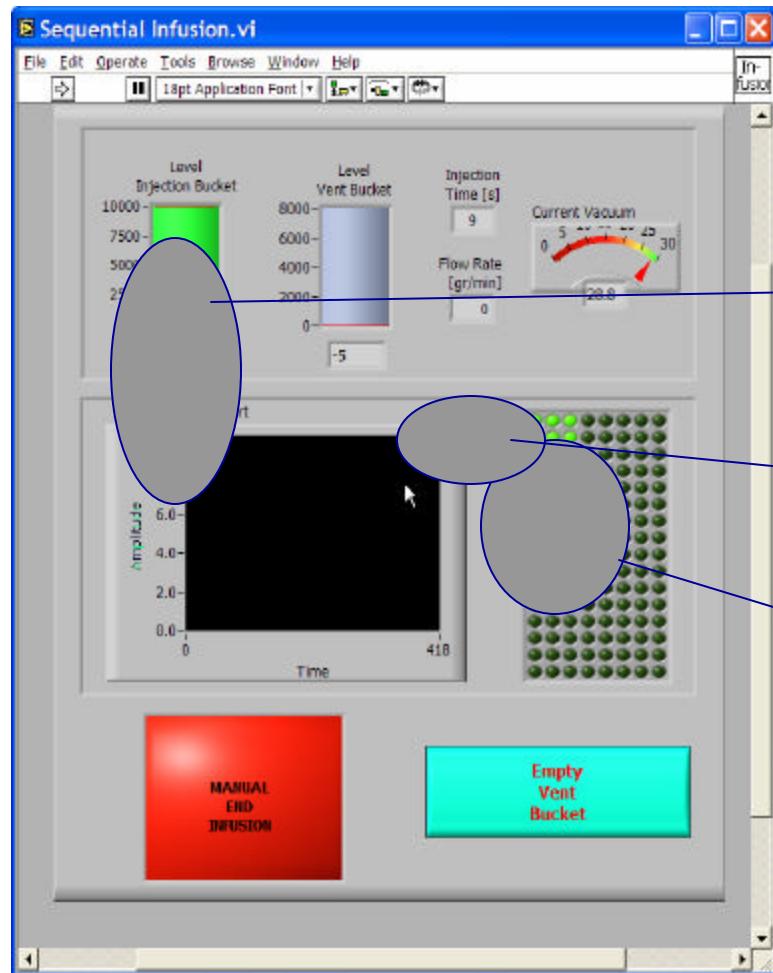
(c)



(d)



# Automated Infusion End



- A) Minimum Resin Amount Infused
- B) Net gain into Part below 10gr/min
- C) All sensors are wetted out

→ Infusion stops when  
 $A \wedge B \wedge C = \text{TRUE}$

# Help Through Work Instructions

A screenshot of a Windows application window titled "Help Window Call.vi". The main title is "WORK INSTRUCTIONS" and the subtitle is "Bag Preparation Step". On the left, there's a sidebar with links: General Instructions, Drawings, Material Requirements, Safety Requirement, Pictures, Tacky Tape around tubing, Bagging Start, and Bagging End. The main content area shows "1. General Instructions". It describes the placement of two injection lines and one vent, and provides a table mapping injection lines to valves. A note at the bottom says to put weights on the tubing just behind valves to restrict movement during injection. At the bottom right is a "STOP" button.

**WORK INSTRUCTIONS**  
**Bag Preparation Step**

**1. General Instructions**

This part requires 2 injection lines and one vent. The width of each omega tube is 12" connected to 8" tubing. The first injection line is placed just off the fabric on the distribution media near sensor (1,1), (1,2) and (1,3). The second injection line is placed on the distribution media on sensor (4,1), (4,2), (4,3). The vent is placed off the part and on the breather cloth. Wrap tacky tape around all tubes and attach it to the nearest location of the tool-based tacky tape. Pass tubing through valves:

Injection Line I	→ Valve 8
Injection Line II	→ Valve 7
Vent	→ Valve 6

Put weights on the tubing just behind valves to restrict tube movement during injection. Add water to the injection bucket and place liner into it. Cut the injection tubing in an angle to allow unrestricted flow out off the bucket and attach to liner

**STOP**

Lay-up

A screenshot of a Windows application window titled "WORK INSTRUCTIONS" for the "Lay-Up Step" with "Part ID: Example 2". The sidebar has links: General Instructions, Drawings, Material Requirements, Safety Requirement, Pictures, Preform, Peel Ply, Distribution Media, Breather Cloth, and Tacky Tape. The main content area shows "1. General Instructions". It describes the material requirements for Part "Example 2". Below it is "2. Drawings", which displays a technical diagram of a composite part. The diagram shows a central rectangular area labeled "30" Peel Ply" with a dashed line across it. To the right, there's a vertical section labeled "2" Breather" with a small bracketed note "4" (Valve 1 area)". At the bottom right is a "STOP" button.

**WORK INSTRUCTIONS**  
**Lay-Up Step**  
**Part ID: Example 2**

**1. General Instructions**

Part "Example 2" consists of 6 layers of 24oz. woven fabric with dimensions of 45in by 14in. The fabric has to be weighted before being placed on the tool. The fabric corners have to be put over sensor (1,1) and (3,7) to allow sensing of 21 SMARTmolding sensors (see Figure 1). The peel ply layer (50in by 16in) has to be placed over the preform. The distribution media slightly narrower (45inby 12in) than the fabric is placed on the peel ply leaving 2in short to the vent location (near sensor (3,7)). Breather material (12in by 2in) should connect the fabric and the tool. Finally, tacky tape has to be placed around the circumference (2in spacing) of the peel ply.

**2. Drawings**

30" Peel Ply  
2" Breather  
4" (Valve 1 area)

**STOP**

Infusion

- Includes instructions about lay-up, infusion and staging using HTML
  - MSDS
  - Pictures
  - AutoCAD drawings
  - Video

# Report



## Lay - Up Information

Operator: Hope Deffor

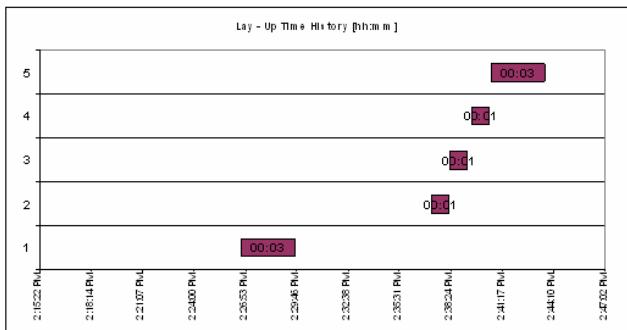
Start Date/Time : 1/28/2003 2:25:21 PM  
End Date/Time : 1/28/2003 2:40:39 PM

### Seq Material

1	E-Glass 324-2407 Woven Roving
2	Peel Ply Green
3	50% Shading (Awning Material)
4	Breather Cloth
5	Tacky Tape (T<250F)

### Weight [gr]

1950  
0  
0  
0  
0



## Status Information

Operator:

Dirk Heider

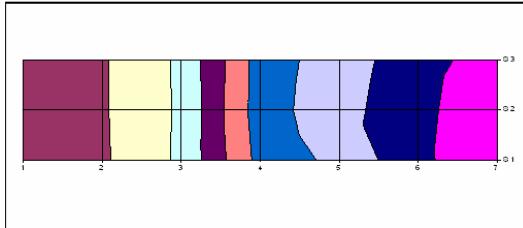
Start Date/Time : 1/28/2003 12:12:02 PM

End Date/Time : 1/28/2003 12:12:02 PM

Calculated Fiber Weight-Fraction : 0 [%]  
Final Part Weight : 0 [gr]  
Total Production Time 12:00:00 AM [hh:mm]

### Comments

## Sensor Data



Step Time : 29.6 [sec]  
Max Intusion Time : 296 [sec]

Valves			
Date	Time (open)	Time (close)	valve
1/28/2003	3:31:46 PM	3:34:59 PM	6
1/28/2003	3:34:59 PM	3:42:12 PM	7

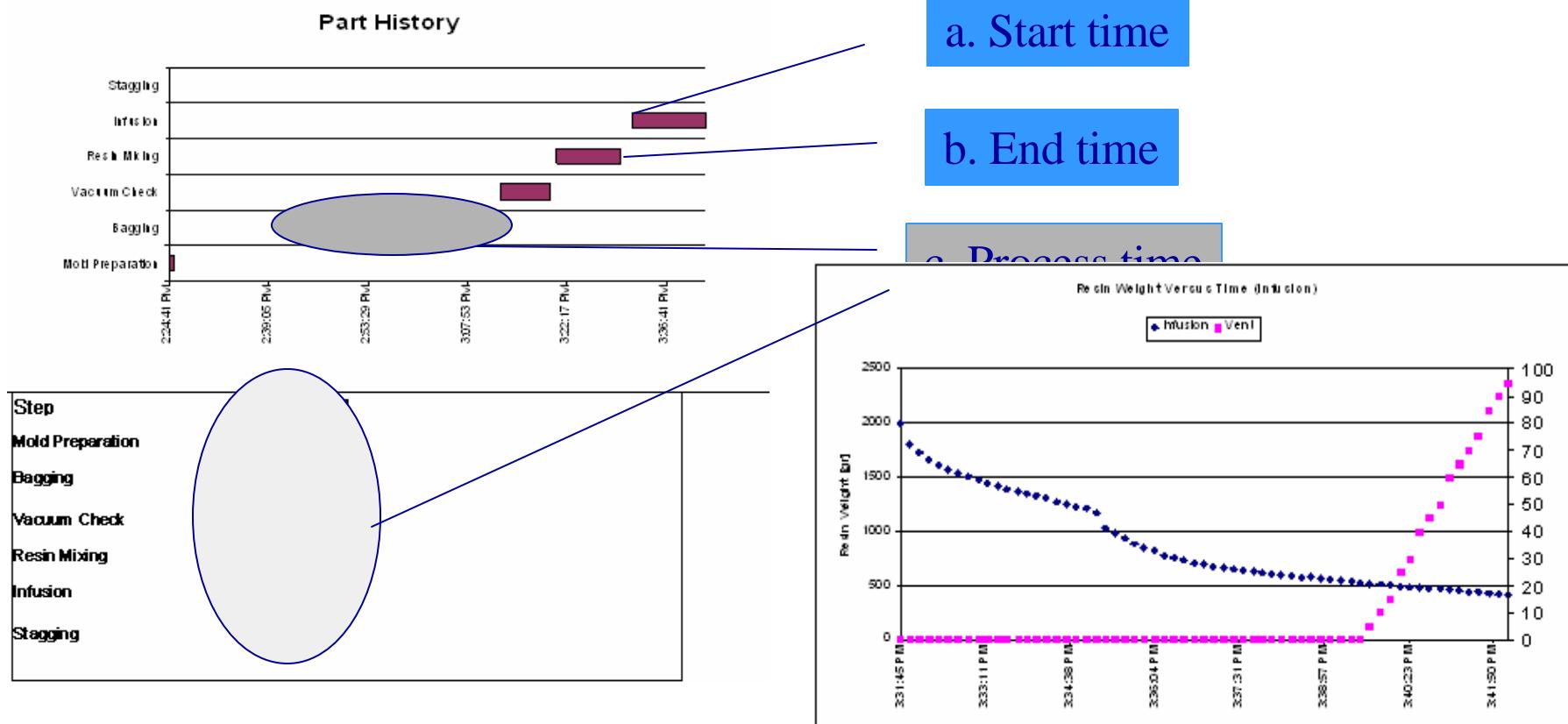
## Basic Information

- Operator
- Material Sequence during Lay-up with Cycle Time Info
- Opening/Closing of Valves
- Weight and Fiber Volume Info

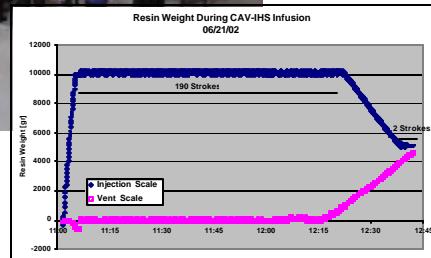
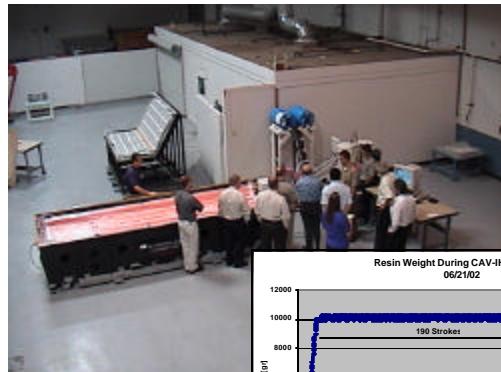
## Charts

- Cycle Time for each processing step
- Arrival Time of Flow Sensors

# Infusion History Report



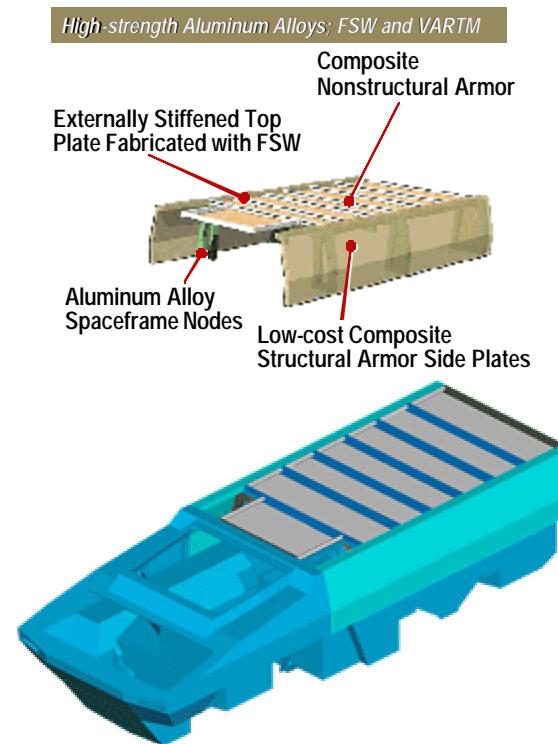
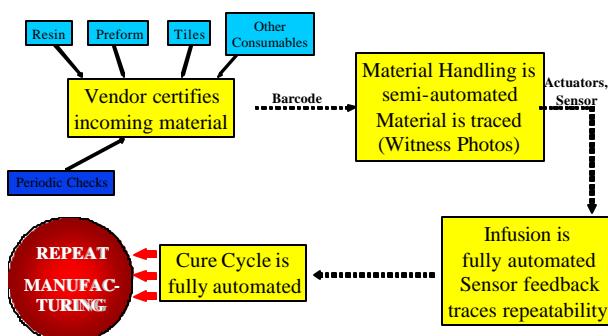
# IPC Demonstration PEGASUS / CAV IHS



TOTAL Automated

Infused Weight: 128lb

## SOFTWARE



- Wheeled Platform Offer Breakthrough Technologies



- Vehicle Helps Army Meet 2008 FCS Timeline
- Wheeled Vehicle Designed and Built In Less Than 8 Months



# Fun to Watch!!!



# BETA-Site Technology Transition

